RUNNING A MACHINE SHOP

BOOKS

by

F. H. Colvin and F. A. Stanley

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PREFACE

Long·years of experience both in the shop and in close contact with shops of many kinds and in many localities have made us familiar with many of the problems that present themselves to shop managers in general. Personal and friendly relations with managers of many successful shops and close observations in hundreds of others have shown many of the reasons for both success and failure. As a result of these first-hand observations, it has become evident that regardless of the size of the shop. many of the problems that confront the manager, or the "boss," are practically the same.

With this experience in mind, and also as the result of having had many problems presented to us for solution, we have been forced to the conclusion that many problems are common to all shops, and that many who are responsible for shop management may be assisted in their work by these observations. The information and suggestions contained herein come from varied sources and both large and small shops. Plans and methods which have proved successful in one shop may fail in another because of entirely different conditions in the other shop. The kind of work, the efficiency of the machine equipment or of the men, the relations between the men and the management, living conditions in the town, and many other factors have their effect. In any case, it will probably be necessary to *adapt* the ideas, rather than to adopt them in their entirety.

The authors do not believe that they know all the answers to the many problems presented in the running of even a small shop. It is, however, in the hope of assisting in the solution of some of the many problems that are involved in running a machine shop that this volume has been prepared.

THE AUTHORS.

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CHAPTER 1

MODERN MACHINE-SHOP PRACTICE

INTRODUCTION

A comprehensive survey of modern machine-shop practice becomes increasingly difficult because of the constant changes in machines, methods, and materials used even on similar work. Instead of a few simple machines, each with a fairly well defined class of work to perform, we now have varieties and modifications that change with astonishing frequency. Where the planer and shaper formerly handled all flat-surface work, the milling machine, grinder, and, more recently, the broaching machine are now used almost exclusively on production work. In addition to new machines, there are new methods made possible both by new cutting tools and by new materials. All these factors make it necessary for the men who are engaged in machine work, whether as owners, managers, or workers, to have a wider knowledge than ever before of the things that affect their industry

With all the changes that have taken place, however, the principles of machine operation remain the same in most cases. If these principles are understood, it is much easier to change the practice to meet the changing demands. With an understanding of these principles as a background, past experience should be of great value. But if this past experience closes the mind against new methods or prevents investigation as to their merit, it may easily be a handicap. The improved machines, methods, and materials now available make possible better products at lower cost than ever before. To secure their full value, they require men of wider knowledge and broader vision in all executive positions from general managers to foremen.

Since many of the elements of machining are embodied in the operation of the lathe, considerable space is devoted to this

machine, which is one of the basic machine tools used in the shop. The drilling machine and the planer and shaper also receive considerable attention, while milling and grinding are by no means neglected. The advances that have been made in the materials used for cutting tools make it necessary to devote considerable space to this subject, this space being divided between single-point tools, such as those used in turning and boring, and milling cutters or multiple-cutting tools. The introduction of these new cutting tools has added to the problems that confront the shop executive, especially in the small shop.

With the demand for large production at minimum cost there are few operations where the new tools are not likely to be economical. But their adoption may involve the purchase of new machines that will not only be faster but more rigid in the support of both tool and work. Then too, the faster the machining operation, the more important the handling time; and jigs and fixtures may have to be redesigned to meet the new conditions. But greater cutting speed is not the only deciding factor in favor of the newer cutting tools. Longer life between grinds is often of sufficient value to warrant their adoption. In some jobs, such as cutting the ring grooves in aluminum-alloy pistons, the use of carbide tools obviates the necessity of changing tools during an entire day's run, sometimes for even longer. The hardness of the material so reduces the wear that the groove width can be maintained over a long period. There are also cases where the turning tool itself is a diamond in order to give the finish desired as well as to maintain size. These problems do not, as a rule, confront the management of the small shop.

Although the small-shop manager is usually limited as to the capital that can be invested in new machines and tools, nevertheless he needs to know what equipment is necessary and economical if and when he must increase his output in some of his lines. He should know something of the methods of the big shops so that he can adopt, or adapt, some of their practices to advantage. His shop can probably work best with the various types of machines grouped in departments, as in the older shops. But there are likely to be times when by regrouping a few of his machines he can secure some of the economies of line production.

This consideration should be borne in mind when selecting new machine equipment. Not only the kind of machine but

the question of individual motor drive must be considered. From the question of first cost and power consumption, the group drive has advantages: It requires less expenditure in motors and averages the power load to better advantage. But when machines are to be moved, either for realignment for a certain job or because of shop growth, the individual motor drive may be worth more than it costs. This is particularly true on special machines that are likely to be in demand for overtime work at certain seasons.

Plant layout also affects the efficiency and management methods. And although few shops have a free hand in this respect, owing to limitations imposed by the building itself, it is of interest to know how other shops are laid out. For this reason it has been thought advisable to include plans of shop layouts for different operations. Some of these are for shops larger than the average, as is the case in most automobile plants, but these contain suggestions that can be modified to solve some of the problems of the smaller shops. In the same way there are shown high-production methods that would be out of place in the average shop. But there are few shops that cannot find some suggestion applicable to their own work.

It is seldom practicable to give full details of the operation of each machine in the different groups, or necessary, for each machine builder issues instructions for the operators of his particular machine. Furthermore, it is not possible to show every machine in each group. The machines illustrated have been selected with a view to giving a general idea of what is available in the different lines and to show some of the work of which they are capable. From these illustrations the practical shopman can determine which type of machine will best handle the work he has in mind. Or having one of the machines available, the examples shown will suggest methods of using the machine and give hints of tool setup.

The section devoted to the machinability of metals and other materials should be especially useful to those whose experience has been confined to the more common iron and steels. While this section is by no means complete, it contains information that will serve as a guide in machining other materials of a similar nature. If additional information is needed, the makers of the material in question should be consulted, for they are

constantly experimenting to find the best method of handling their particular product. We especially recommend Brady's *Handbook of Materials* as a reference for many kinds of materials because it contains much of value to any shopman who wishes to be up to date.

Other sections take up the questions of estimating on work of various kinds; presswork with its many problems and great possibilities of economical production; toolroom work, which includes the making of jigs and fixtures as well as heat-treating; and additional topics of practical value to the man who must get work out accurately, rapidly, and economically.

General Considerations.—There are many general considerations to be taken into account by managers of shops of any size. Some have to do with nontechnical problems, whereas others involve a knowledge of many different branches of machine-shop work.

Some phases of the problems of running a machine shop can be classified in distinct lines, such as shop layout, machine equipment, production costs, and other items; but many are not easy to classify and are gathered under this general heading so as to be easily found and consulted. They include a number of different subjects, but all have a direct bearing on the successful running of machine shops of different sizes.

These problems run from selecting the location of the building and arranging the machinery to dealing with men and women of widely varying temperaments and abilities, to getting business, to meeting the pay roll, and even to keeping clear of the sheriff. In the small shop these problems fall on the shoulders of one man. In larger plants the various duties must be delegated to others. But in all plants, regardless of size, one man, or a number of men working together, must make decisions that may spell either success or failure.

This is one reason why shops of moderate size can frequently produce goods for less money than some of the huge plants. Where the shop is small enough to have one man keep his finger on the various departments, shifts in schedules can be made quickly and decisions rendered in much less time than in very large organizations. In many such plants these advantages overbalance the advantages of somewhat lower manufacturing costs and slightly cheaper materials which the larger plant has.

The fewer steps between the shop and the manager, the better the results.

Underlying Problems.—Whether we are confronted with the task of running a machine shop with five men or with five hundred, many of the problems are very similar, if not identical. Both classes of shop include some or all of the following questions:

1. Selection of location.
2. Kind of building.
3. Location of machines and materials.
4. Handling these materials while in the shop.
5. Operation of the machines.
6. Heat, light, power, and insurance of buildings and materials.
7. Inspection of material and of work done.
8. Assembling the parts into a complete unit or machine.
9. Wages, liability, and accident insurance.
10. Personnel relations, which are important even in a small shop.
11. Apprentices and other training of workers.
12. Cost systems of some kind for estimating and pricing work done.

No set of rules can be laid down to govern all cases. In fact, rules or practices that may be perfectly good today or in one locality may not be at all suitable at another time or in a different place. One of the first things to be learned by everyone responsible for running a shop, or any other business, is that making or laying down a set of rules is not management. There must, of course, be rules for general guidance. But if rules alone could run a business, there would be no need of a manager. All that would be required would be competent clerks who would obey rules to the letter.

Management, in the simplest terms, is in *knowing when to break the rules.* The manager who can decide on the proper deviation from general practice in the largest percentage of decisions is the best manager. And the best is never 100 per cent. Those who rate 60 per cent or better, are above the average.

The greatest single factor toward successful management is the ability to work with and to get along well with people—and "people" includes everyone with whom you come in contact,

from the workmen to the men who buy your product or services. It is necessary to understand and appreciate the problems of others as well as your own. Some managers expect their employees to have as good judgment as they have and therefore cannot overlook mistakes on the part of their men. They forget that if the men had as good judgment as the managers, the chances are that the men would not be working for the management.

Mistakes of any kind cost money, but we all make them, and we should not be too severe unless a man makes the same mistake twice. The average man seldom does this, so that it is usually safer to retain him than to hire a new man who is very likely to make the same mistake.

PRODUCTION

Different shops apply the word "production" differently. In some shops production means a moderate output; in other places it refers to greater volume. The actual rate of production will vary in different plants about as actual volume varies; that is, the different plants become geared to certain volumes and their productivity per unit, or per machine, or per man-hour will vary in about the same manner. The larger the scale of production the greater use naturally is made of high-production equipment.

It is true though that there are few cases where, given a sufficient amount of work to turn out, the given machinery cannot produce considerably more per time unit than it customarily does on its regular schedule. Possibly some improvement in special tool equipment may be necessary in order to bring out improved rates of output, that is, better jigs and fixtures, faster loading and unloading, and other facilities may be called for to add to the capacity of given machine tools. The same may be said of punches and dies and their application to typical forms of power presses.

Any well laid out production line carries a well-balanced flow of work from one tool to the next, and any change in the process or operation at any stage in the line must be done with due consideration for the other elements in the system. In a study of a given group of tools it is often possible to change certain lines of procedure and improve methods of applying holding and cutting tools, fixtures, and other devices to the general advantage of production as a whole.

Sometimes a study of this kind suggests the desirability of introducing a new machining operation at some step and brings to light a better general way- and timesaving process in the sequence of operations to be accomplished.

Production and Special Work.—A lot of jobs formerly considered to be of a special nature have in recent years come into the regular production class and are handled like any other accurate class of work. These jobs were sometimes in the precision class and produced in the toolroom only as special undertakings. Regardless of close limits, precision work is now produced on a production basis affected only to a slight degree by the requirements of the designers. New machinery, which was developed for finishing work by improved methods, has really increased output and enabled a still higher grade of work to be produced.

Toolrooms as well as production departments have benefited by new designs of machine tools and appurtenances. Operations in jig boring, die making, and the like, and, in short, all classes of tool work where accurate location of hole centers is important have been simplified by the use of the newer classes of tools.

Many special tools are now built in duplicate or in even larger numbers, using modern facilities for making them practically on production lines, jigs being bored several on a lot or dies similarly treated. The advantages gained by such precision and convenience in toolroom operations have been duplicated in the shop departments by improved equipment where formerly much finishing was required after the work had been passed through the usual machining operations.

It appears that machines developed for better production have at the same time improved the articles made on them and have helped the general movement of operations along the whole line. This is because the work coming from precision tools caused no loss of time and the parts were in better condition for immediate assembly with little or no waste in inspection.

As an illustration of improvement in time of output a recent instance shows the results from installation of a newly designed tool used for machining a variety of accurate work in moderate-sized lots. A typical work piece representing one size of several similar pieces had required by earlier methods over 3 hours to produce. Then an entirely new type of tool was purchased.

The time for the same operation on the new machine was reduced to less than one-fourth the former time, and the work was an improvement over that produced by former equipment.

This experience is commonly found in shops where wise judgment is displayed in installing the right kind of tools. Double advantages of time saving and improved quality in the work turned out are natural results.

Production Costs and Volume of Work.—Although methods of production are varied according to the volume of work to be put through in lots, nevertheless even fairly small runs of work are frequently handled on what is really a production system.

Consider such tools as, say, the turret lathe and the grinding machine. These belong to a class of machines used economically on short runs of work as well as long production undertakings, and they prove leading factors in cutting down time and improving general quality of work turned out. In their most highly specialized types, tooled for maximum production purposes, they may be outside the needs of the average small shop; set up for long duplicate parts, they bring about marked reductions in costs. Plants building automobiles, firearms, sewing machines, etc., make the widest use of highly developed tools of this character.

The use of simple dies in the punch press is an example of production setup for what might be considered small-lot production, though the advantages of speed and duplication of work are gained even on relatively short lots. With more highly developed press tools that use automatic feeds, the output is increased greatly and unit costs are cut correspondingly. Here again the scale of production determines just what types of dies to apply. The first cost of such tools is unimportant on large lots, for they are readily paid for in the timesaving features they incorporate in their construction. Naturally, on small lots the die cost is not so readily absorbed.

Other special tools, jigs, and fixtures, for example, are ordinarily designed also in accordance with the volume of work they are to handle. Large lots of milling and other work can usually be run through at much lower time rates where the tools are made for larger runs. Smaller lots require discretion on the part of the management as to just how far to go with building special fixtures.

General Divisions

Production problems may be divided into three general headings: small-lot production, medium-volume manufacture, and mass production.

Small-lot Production.—This applies to shops making comparatively few parts of a kind in a lot. "Production" is here used in the sense that the lot is carried through on a repetitive basis to simplify the cost of operations and assure duplication of parts within prescribed limits. Thus, a series of 100 machine spindles could be made on a "production" basis with great economy as compared with individual handling of each unit. The extent of special tooling for such work depends upon the total value of the job.

Medium-volume Manufacture.—This classification includes such lines as general machine tools, especially the smaller sizes of drills, lathes, and punch presses, textile machinery, air compressors, Diesel engines, pumps, electric motors as built in all but the largest factories, oil-tool joints and other oil-field apparatus, oil burners, rock drills, and tools for many other lines of work.

Mass Production.—Mass production is typified in the automobile plant and in the manufacture of sewing machines, firearms, electric apparatus, household equipment, business machines, radios, telephone equipment, small tools, agricultural equipment, dairy machinery, and allied lines, and a large number of other classes of machinery.

Each of these three groups may be greatly augmented when we look outside the machinery and equipment lines. Among these we must consider the number of plants engaged in producing watches and jewelry, locks and hardware, plumbers' supplies, valves, and a thousand and one items in common use.

Common Principles

Whatever the volume of production, certain principles underlie the general conduct of the organization engaged in making equipment or commodities requiring the shaping and application of metal parts.

Let us disregard business administration for the moment and consider only the engineering angles. Some of these problems may be presented as follows:

Design.—This presupposes knowledge of and selection of materials to conform to such requirements as the following:

1. Suitability to presumable market.
2. Stability in service.
3. Capacity to meet competitive prices.
4. Adaptability to general machining conditions.
5. Facility of assembly.
6. Simplicity to meet conditions 4 and 5.

Conditions 4, 5, and 6 are related closely to shop procedure and after selection of materials and design should be studied from the point of view of practical manufacture. This applies to small volume and medium and mass production; the volume will determine largely the methods and details of the factory.

Volume will also determine in many instances whether the product or its elements are best machined from solid stock, forged, cast or die-cast, or stamped. Where any of these processes are suitable for the class of product, the decision rests upon costs of tools, such as special dies, etc., which may or may not be justified, according to the character and amount of work.

Effect of material on design will be conspicuous where either stamped work or die-cast details are adopted. This applies particularly in the case of many specialties, details of business machines, and other lines where light parts, free from machining difficulties, are employed.

Routine and Planning.—The course of procedure for a project through the plant will depend upon such factors as these:

1. Are certain elements to be sand-cast, requiring patterns?
2. Are forgings required?
3. What parts go to lathe, turret lathe, automatic screw machine, milling machine, punch press, etc.?
4. What parts are to be die-cast to eliminate most machine work?
5. What is to be the order of operations so far as sequence is concerned?
6. What parts are purchased as commercially made units?
7. Are patterns made in the plant?
8. Are forgings made in the plant?
9. Are castings made in the plant?

Equipment.—The present equipment of the plant or the equipment that it may seem economical to purchase will have an impor-

tant bearing upon the order in which the work in its various elements is routed through the plant. This, in any case, must be determined from a practical and commercially feasible point of view—whether we shall

1. Mill, grind, or plane flat surfaces.
2. Turn work in the engine lathe or turret lathe.
3. Drill parts under single-spindle or multispindle machines.
4. Finish all parts by grinding or only such parts as require precision finish.
5. Use hand screw machines or automatics.
6. Drill thin steel plates or punch them.
7. In general, use general-purpose tools or single-purpose tools.

Raw Stocks.—The general plan of producing a given lot of parts and the equipment to be so employed will establish the basis for selecting the raw materials for the work. Thus:

1. If screw machines are largely used, shall we carry a considerable range of sizes of bar stock to approximate closely the finished sizes of the parts? Or shall we select a few major sizes and then turn off more or less material in the operation?
2. Can we settle this question entirely upon a basis of amount of work to be produced? Or are the costs of too varied a stock list a greater extravagance than the wasting of more material in cutting down oversize stock?
3. Similarly, with strip metal for sheet-metal stamping, shall we hold large inventories of such stock on hand, or shall we reduce the number of widths to a general formula answering for the greater portion of the requirement?
4. Shall large stocks of castings and forgings be kept on hand, thereby tying up funds in raw material in storage?
5. How far shall we proceed with reduction of materials before ordering in new supplies?
6. When can we take advantage of low market prices on materials to stock up against future advances in prices?
7. To what extent should we use the perpetual (daily) inventory to assure our stock room against the depletion of raw materials?

Routing of Work.—The routing of a given piece through the plant will vary with the character of the work and with the equipment available for performing the sequence of necessary opera-

tions. A small lot of spindles in the small shop would go through the following process:

1. Lathe work, including boring and turning.
2. Boring taper hole and cutting keyway, if any.
3. Heat-treating.
4. Grinding.

In larger lots the automatic lathe could be resorted to for roughing the work down rapidly. Internal work and grinding would follow much the same course as with the smaller number of spindles.

Where a greater variety of operations is required, there is marked advantage in the use of special-purpose tools.

Jigs, Fixtures, and Dies.—The character of the special tools of this sort is fixed by such conditions as

1. Number of parts to be machined in a lot or in a given number of lots.
2. Physical size of the parts.
3. Machines in which the work is to be handled.
4. Degree of accuracy required (in some cases this is the main determining factor); the degree of interchangeability sought, whether full or selective, will usually fix the type of special tool best adapted for such precise work.

Inspection.—Inspection may be carried on in simple fashion on certain work, but for general production of interchangeable character it must be considered of prime importance. Inspection may be by the following:

1. Individual pieces at the machine for each operation.
2. Occasional pieces at the machine.
3. Inspection through the fact that work from one operation will not enter the next fixture if inaccurate (applies to certain classes of work only).
4. Inspection of all parts entering parts stores before going to assembly.

Gages.—The detail of gages is tied in with inspection and with the general system of limits and tolerances established for the plant or for the various classes of work produced. The setting of limits and tolerances is a function of the drawing room and should be carried out upon the basis of very broad experience in manufacture.

Tolerances are fixed by

1. The general size and character of the work (full interchangeability or selective).

2. The facilities for doing the work (beyond certain limits the usual equipment is not adequate).

3. The type of fitting parts, whether cylindrical, tapered, threaded; and the type of fit, whether running, sliding, force, shrink, or any modifications of these.

4. Conditions of assembly; it must be understood that even if accurate fits are unimportant in certain cases, variations may handicap assembling operations greatly.

Assembly.—Assembling processes may be complete for one machine, as in the erection of a certain size of lathe; or there may be preliminary subassemblies from which the entire machine is built up, as with business machines. These subassemblies may be stored in advance and drawn from the stores for final assembly as required. Controlling factors may be stated as follows:

1. Character of the product.

2. Volume of production.

3. Flow of parts through manufacture. Some details may be produced far in advance of others, because of the setup details of the machine, as, for example, many classes of work where long runs are desirable.

4. How far can unit designs be extended to adapt certain groups for use on various types of products—for example, a gear box for a series of millers, or a battery of key levers and mechanism for different widths of calculating machines? Such unit constructions, so far as they are used on different models of machines in the same class, may be built up in advance of the main assembly.

With reference to (2) above, the size and volume of the work will usually cause selection of jig design as between simple templet types, bushed plate jigs, box jigs with snap lids, roll-over jigs, trunnion types, jigs which roll from spindle to spindle along a track. Any or all of the above may be for single-spindle or multiple-spindle drills.

Power Considerations.—Application of power may be by

1. Group drive.

2. Individual motor drive.

3. Combination of above.

The division between these methods rests upon certain established production lines in the plant; whether the departmental principle is followed or the "small shop" arrangement with its complete group of tools for producing complete a given detail. In either of these plans some machines may be individually powered and some powered in groups, depending upon machine loads and a balance of considerations between economy of large numbers of small tools on a big motor and large numbers of motors on individual tools where connected horsepower charges must be kept in mind.

Cost Analysis.—Detail costs must be taken from each operation and studied with a view to reduction of time and other elements of cost. Actually, value of equipment, such as cutters, jigs, etc., should be considered in cost analyses. Balance costs with simple tools against costs with more complicated setups. With methods fixed, every operation cost should be studied and the more expensive ones dealt with first. These studies will lead to or be based upon

1. Time study.
2. Motion study.
3. General method and process. Can these be changed to advantage? Shall the operation be transferred to a different type of machine?
4. Particular attention to assembly costs. Is too much filing and fitting necessary? Is a certain amount of machine work done in assembly setup? Are adequate fixtures used in assembly? Is the assembly line a straight progressive unit? Does the assembly department have to look out for oversights in manufacture and inspection?

Handling Materials and Work.—Facilities for moving materials and parts in progress through the plant include trucking and trolley apparatus, tote boxes, etc. Their purpose is

1. To save time and effort.
2. To prevent injury to parts and to workmen.
3. To facilitate recording of work progress.
4. To facilitate handling parts in and out of stores.
5. To form storage for parts at assembling benches.

Advantages of Mass Production.—In spite of the general publicity given the subject, many persons seem unaware of the significance of our mass-production processes with their auto-

matic and semi-automatic means of manufacturing large-scale duplicate work with resulting economies in factory costs. Along with this, the convenience of interchangeability for replacement parts so commonly required in various lines, as in the automobile industry, is important.

The advance in this system of manufacture has been accompanied and aided by similar progress in types of production machinery and in the improved character of the work turned out on such equipment. It might be emphasized here that there is little relation between the general run of finished machine parts today and the corresponding class of work twenty or more years ago As an example consider the accuracy of finish in cylinders, pistons, rods, gears, and bearings. This holds true for other lines of common articles. Commercial manufacture on any large scale of oil burners, small motors, vacuum cleaners, and a host of other articles would not be economically practicable without the mass production methods now so generally employed in well-developed industries.

The lesson the smaller plant learns from this is largely in the use of practical manufacturing limits and tolerances obtained with suitable tools and held to by proper gaging devices. A shop does not need to be a really large place to enjoy the leading advantages of such systems if it applies the essential principles. For, although a small shop cannot afford the special-purpose machines of the larger factory, it can turn out its work on an interchangeable basis with a small percentage of hand fitting, if parts are made in the machine departments by modern methods.

POINTS IN DESIGN

Fix Design before Production

One of the evils of the modern industrial situation is the attempt occasionally made to place on the market a line of equipment or specialties before the design of the article has been tried out to a degree where it has a chance to remain fixed for a reasonable period of time. By "reasonable" is meant sufficient time to bring back to the principals the cost of the project, if no more. If no profit is derived from the venture, it should at least liquidate its cost before redesign of the product becomes necessary along with the unavoidable accompanying expense of re-equipping plant departments for the manufacture of its successor.

Points to Be Considered.—There are several ways in which a going industrial organization may become involved in a hazardous situation in connection with the production of some commodity, or piece of equipment, even though the project may appear a feasible one to the backers of the undertaking. Possible hazards are more obvious to the sophisticated manufacturer than to his less experienced contemporary, but hazards exist for all classes of industrialists, and in the long run any attempt to market what is at the moment an unmarketable product has resulted in much waste of time, effort, and capital.

Articles are unmarketable for several reasons: They may be ahead of the time in the sense that the mass of possible customers feels no especial necessity for purchasing them, and even the most advanced sales methods may fail to convince a sufficiently large group of buyers to make the producer's efforts really worth while. They may have too high a price to attract any appreciable percentage to the public, particularly during a period of industrial stress and forced retrenchment. When placed on the market and put into actual service, they may exhibit a number of undesirable qualities which may force the originators to reconsider and modify certain details, if not redesign important elements of the entire article.

Business Influences.—Possibly, the selection of wrong materials has been made, as a measure of economy or because of lack of knowledge, and failure to satisfy customers has made extension of sales difficult. Bad news travels swiftly and word of mouth can squelch a distributive project as well as guarantee its success.

In almost any field in which the major portion of buyers is composed of nonindustrial and nontechnical individuals, the sales of manufactured articles, such as household equipment, are largely based upon details of convenience and attractiveness of the product or on personal selling efforts upon the part of the distributor. In almost any group of products in a specified field that are made by different factories, one or more will be certain to find a large demand while many of the others will fall short of attaining a profitable position as a manufacturing project.

The question then arises in connection with the latter as to how far a device should be remodeled and whether redesign will eliminate the elements which seem to block all avenues of sales expansion. At this point the producer is faced with

the problem, How far can he afford to venture in redesigning, retooling, and re-equipping generally to turn out an improved article?

Plenty of Examples.—A firm took over the production of a line of apparatus in the domestic field after learning that about $200,000 had already been expended on the making of tools and devices for the manufacture of this specialty. This expenditure appeared justified, however, upon the assumption that the product had qualities which would make an appeal to prospective users. Investigation following the unsuccessful selling efforts disclosed so many unsatisfactory details of construction that radical changes in design appeared to present the only feasible way out of the difficulty. This would involve the rebuilding of the entire outfit of special tools and, as in many other instances, a decision was required to determine whether to continue with the project or to drop it completely.

In this case the entire affair was abandoned, not entirely because of the reasons suggested, but because, added to them, was the belated discovery that the current market was already beginning to grow away from that particular type of equipment. In America, at least, we seldom return to an abandoned fashion in household apparatus, or industrial equipment either, for that matter. Under such conditions something more than the mere revamping of a device would be called for, even though its mechanical features were perfect, which in this instance did not happen to be the case.

A preliminary survey of the field for the project would have warded off this unhappy venture with its entailed waste of effort and money, but this is only one of many similar instances running through the records of our industrial history. Perhaps one lesson is that it often pays to accept the loss up to date and waste no further effort in trying to recapture a doubtful opportunity by the redesigning of an article in an already vanishing class of appliances.

Time for Redesign.—There is a time to redesign and a time to sit tight, but this depends much upon the original design of the appliance. Assume that it is correct mechanically, effective in operation, conveniently manipulated and controlled, and, finally, produceable at a price within the range of a reasonably large market. If, then, it does not reach an appreciable proportion

of the buyers in the field, there is something besides the character of the article itself that is blocking anticipated distribution.

No matter how we approach the matter, care and judgment must be exercised or we shall never assess the product at its true worth. Either "parent-fashion" we shall overestimate its superior qualities and minimize its defects, or in disgust we shall consign it to the scrap heap. More likely we shall pursue the former course and resist attempts upon the part of outsiders urging toward a new and improved model with its attendant expenditures for facilities necessary because of the new features they presume to recommend.

It cannot be said, though, that this course is any worse than to make the repeated changes in model after model before any special trial period has established or condemned the present form of the product. In days when company reserves were common features of industry, officials and stockholders often groaned under the mounting accumulation of expenses due to an unsettled policy whereby each lot of work was modified somewhat from the preceding batch and no one type persisted long enough to wipe out the special expenditures based upon retooling for a different piece of design.

Advantages Today.—There is an opportunity for adequate design to be applied to new and improved lines of products of many classes and types. There are accessible many sources of information upon every angle of metal-parts design and production. The metal specialties markets are to be reached most fully by carefully considered and meritorious articles of manufacture. To hold these markets, proper design must be followed and well-thought-out methods of fabrication adopted.

There are also available today materials that are more satisfactory in character than was formerly the case. New alloys, stainless steels with their heat-resisting properties and long life assure low maintenance charges for commodities in which they are employed.

The interests of all concerned in the supplying of materials and machinery and in the manufacture and use of metal parts will be best conserved by a reasonable degree of attention to fixing the design of new products before they are placed en masse on the market. They will then be reasonably sure of a regular and advancing position in the country's growing inventory of essential

items of production and use. The very fact that they are manufactured from newer and more serviceable materials will stimulate their distribution even in markets now restricted by economic conditions and limited buying capacity upon the part of very large groups of former enthusiastic consumers.

CHANGES IN DESIGN

A shop putting out certain products of more or less general interest, for example, some kinds of home appliances, must be prepared to redesign its line upon occasion, but it is often difficult to know just when the market has been covered with the product already made. Some articles remain more or less fixed in type and form for long periods. Others have something of the same style feature as that of automobiles which reach a wide market through style appeal as well as through strictly engineering advances.

Definite Improvements Demand Redesign.—In times of limited buying the appeal to the eye has much to do with marketing articles among people with ready resources. But to a larger class of people nothing is likely to be salable except upon a basis of strict necessity. These people base their choice upon sheer mechanical merit rather than follow the style changes which might create an interest among more prosperous neighbors.

Definite advantages exhibited in new or improved designs are important to a market following the makers of vacuum cleaners, washing machines, oil burners, electrified equipment generally of use about the home kitchen. Improvements in design which lead to convenience and economy of operation will be real aids in finding a wide market even in sluggish periods of general business.

Although redesigning of this type of appliance, as well as of others, leads to a great expense for new special tools, such as jigs and the like, this expense can be justified upon a presumable liberal market for the product. Production of such articles must be aided by intelligent and reasonable sales effort or the project may prove more of a burden than the business will stand. Care must be used in determining how far the firm can go with special tooling expense in getting out new or better designs on any metal product.

Under usual business conditions wise expenditures for special tools and fixtures will be offset in the course of a reasonable run

of production. This "reasonable run" must be fairly well assured, however, if the shop is to take under consideration retooling the entire job.

Designing Problems of the Shop

The small shop, like the larger one, has more or less special designing to handle for customers who wish the plant to take care of layouts as well as build the work. Much of this work relates to jigs, fixtures, press tools, and other special equipment. In the tool and contract shop the design of such special tools is often left to a practical draftsman with years of shop experience behind him. He usually appreciates the special qualities of the job and has come to consider certain conditions that were formerly of less importance.

High-speed-steel Tools.—For instance, the general use of high-speed-steel tools for drilling, milling, and other operations and the use of carbide tools have brought about a definite change in regard to rate of loading as compared with actual machining time. This means that every effort is now necessary to cut down *handling* time of work in and out of jigs and fixtures. The cutting time is usually so short that seconds lost in placing and removing the work become a large percentage of the total time of operation for a given piece.

As an example, consider the high speed at which simple holes are drilled. Formerly a few seconds more or less required for placing the piece in the jig and removing it was of little importance. Now the drilling is done at many times the rate, and slow-acting clamps are no longer usable in the modern shop.

Multiple and Gang Drills.—Then too, the use of multiple and gang drills has cut down drilling times, and this also forces us to use rapid means of clamping and releasing work. Further, the added load put on the jig by the use of a group of drills has made more rigid tools necessary to resist deformation of the jig and consequent inaccuracy in the drilled piece.

Even on single-spindle drills alone, the use today of modern quick-change chucks for drills, reamers, counterborers, and taps enables the work to proceed steadily without stopping the spindle. This brought into use more rapid methods of changing guide bushings, for time can be lost there with clumsy bushings hard to remove and replace.

The practical designer is vitally interested in all methods for cutting down lost time in changing work and bushings as well as

tools themselves. Time study has brought to the front the fact that former shop methods consumed much time unnecessarily in noncutting operations. One of the greatest advances in shop appliances has been in the elimination of waste time. The designer must keep posted on the latest machine tools and their effect on progressive design of allied appliances whether in drills, millers, or other machines. Many milling jobs, for example, are handled more rapidly in the actual cutting process than they are replaced by the new piece after completion of the milling cut.

Materials of Design

One of the important features of modern shop operation already noted is found in connection with the numerous kinds of materials now available for construction of machines, tools, and appliances. Materials are now selected for certain useful properties, such as wearability, strength, resilience, or some other quality essential to the success of the project. Price sometimes has much to do with the selection of grades of steel or other materials, but it should not be the sole factor. Unusual qualities in metals, like other things, must be paid for. Nevertheless, there is considerable choice within reasonable price limits when we are deciding on a suitable kind of stock for a given piece or machine to be designed.

Wide Variety.—Formerly there was little choice in materials. One had to take the castings supplied by the foundry, either cast iron or brass, and the range of steel selection was also very limited. Today the shop executive can hardly keep pace with the development of special kinds of stock marketed for all kinds of purposes.

The endurance of some of the modern materials of construction is remarkable. This fact is displayed in the case of automobile engines, firearms, business machines, and heavy equipment, such as locomotives and other large units. The shop today can find available almost any kind of material suited to his work, whether castings, forgings, rolled stock, sheet materials, or other kinds of stock necessary for the work.

Redesign Necessary at Reasonable Periods

It is well to bear in mind that nothing is permanent and that certain kinds of shop products have to be redesigned from time to time for various reasons, and this applies to the smaller plants

turning out limited numbers of units as well as to large producers of equipment.

PROPER DRAWINGS REQUIRED

It is always desirable to have adequate drawings before a shop starts to build anything in the line of special machines or tools. This is particularly true where a product is to be manufactured regularly. In such instances blueprints are almost always prepared before manufacture begins.

Justifying the Cost of Drawings.—But, with special jobs, and particularly with such tools as jigs and dies, it is still a common practice in many shops to prepare nothing more than the simplest sketch, outlining, perhaps at the best, nothing more than the general over-all size of the work and possibly a few details suggested by simple lines here and there.

The reason, of course, is that the expense of making drawings and blueprints for something not likely to be built in duplicate, or overhauled at any time, appears unwarranted. It frequently happens, however, that drawings are very much needed. Yet the average small shop does not consider itself justified in making anything of the kind, getting along instead with the simplest sort of a layout for a rough record.

What is needed is something in the way of a drawing that can enable the workmen to carry the job through the shop without too much backtracking and redesigning of parts here and there to offset something that was overlooked because it was not included in a drawing. Assembly troubles arise when the parts are not made to fit because of the absence of the proper layout; and tools are often made over just to produce some member that was improperly laid out in the first piece.

The larger plants always have reliable prints to work from, but a very large part of the special tool work, particularly in the punch and die line, has always been made more or less from "air sketches" and samples. This applies of course to the small tool and specialty shop.

Some of these cases where the attempt is made to shift the blame for erroneous work on the shop, where the drawings have been inadequate or even worse, have led to litigation, which is usually an unhappy way to settle arguments. In one case a shop finished a job and the customer refused payment saying the

machine produced faulty work. It was claimed by the shop proprietor that the drawings were faulty. But he had difficulty in showing why he—an experienced man—undertook to build an accurate job from what he recognized as being inaccurate drawings.

Presumably in some cases of this kind, if the man having a job built had to pay for a complete layout satisfactory for the shop to use safely, the cost might prevent him from going ahead at all with the undertaking.

Drawings Show Up Defects.—Customers of small shops are sometimes accustomed to having good drawings prepared while others know nothing about such procedure. They refuse to appreciate the value of a good drawing, or any kind of a drawing for that matter. They do not realize that the lack of a drawing may mean a lot of expensive "cut-and-try" after the work starts.

Frequently a good layout will disclose the fact that the idea behind the device is wrong and impracticable. This shows up when they try to fit numerous elements into too small a space or make impossible timing conditions. Making the details in metal, without drawings, involves much wasted time and effort.

Not only correct dimensions for each piece must be fixed upon at some early stage in the game but also the right materials should be selected after due consideration and study over the board, and too much snap judgment on the part of either shop or customer should be eliminated.

The experienced shop manager will naturally look over drawings at the outset to see that figures are given correctly, and the whole layout will be given close attention before the work is started. But, unless details are carefully shown on the drawing with all dimensions placed properly, there will still be a chance of misinterpretation of some feature of the work.

Clearances and Tolerances.—Misunderstandings can be avoided by giving either the clearances desired or the permissible tolerances. The tables of the A.S.A. for fits of various kinds can be studied to advantage and the class of fit specified by number. These tables give clearances and tolerances and save all argument.

A common difficulty in such things is found where "offhand" drawings carry such instructions as "running fit" or "free fit"

or some similar note. This puts the matter of proper allowances for fits squarely on the shop, and it is usually well to fin l out just what the customer has in mind when drawings are marked in this manner. Although the shop force may be qualified to establish suitable allowances for ordinary classes of fits, "standard" allowances may not be at all what the customer has in mind. This is another point that should be settled before work is carried forward to a point where correction of parts already finished is either impossible or unduly expensive.

Where No Detailed Drawings Are Used.—It is evident that the contract shop rarely makes complete drawings or even partial drawings of press tools unless these are to be duplicated. Examination of methods in scores of specialty tool rooms and tool departments of somewhat larger plants shows that very few drawings are completely detailed for this class of tools. Larger plants handling press tools and stamping work take the same care in preparing press-tool (and other special tool) drawings that they do with manufactured products. Other places commonly leave details to the workman to handle from experience with little other than a sample piece to work from.

Today the greater number of press tools are built up on commercial die sets, eliminating building such die shoes and punch heads with the various ideas held by different shops upon suitable proportions for such units. But the matter of "finding" blanks, determining how the blank shall be "placed" in the die, its relation to piercing tools, and other features likely to be incorporated in a progressive or other die, is largely left for the diemaker to fix to suit his own ideas of the problem.

Comparatively few draftsmen have had sufficient diemaking experience to be able to determine readily the exact manner in which a press job can be handled to best advantage. Not all skilled toolmakers have the same viewpoint regarding a given piece of work. This fact adds to the interest taken in such work but does not help to establish standard practice with respect to layouts or ways of going ahead with general die construction.

RESPONSIBILITIES OF THE SMALL SHOP

The head of the small shop must often serve as consulting engineer, financial adviser, and marketer for his customers The work coming to such shops is often brought in by men knowing

little of machine work or manufacture and as little about design or the handling of a product once it is made. They have an "idea" which may or may not be practical from a mechanical point of view, or from the point of view of a possible market. What is the shopman to do when he has a definite feeling that the customer's time and resources are likely to be wasted in building something that has no special merit and little chance of success in a competitive market?

The Impractical Job.—Sometimes articles in which the practical man sees no merit, do appeal to a popular field. It is therefore difficult for anyone to set himself up as a reliable prophet regarding the commercial outcome of an article that he is asked to develop and manufacture. Still, he usually knows much more about such matters than a customer who has had neither mechanical or selling experience.

Many projects come to drafting rooms and engineering offices, as well as directly to small shops, which apparently have no reason for being made. It is sometimes difficult to convince an ardent inventor that he has been anticipated by various other equally good devices for the same purpose. The history of many "novelties" that have failed will not necessarily affect a man's idea of the advantages of his own.

Discrimination.—Some shops seem to be guided by the idea that if they don't handle a job (no matter how impracticable it may seem to be) some other shop will. In the end it is a matter of human judgment and long-distance use of that judgment. A shop can gain an excellent reputation by using discrimination in taking jobs. Men serious about having designs made and perfected will discover a reliable shop is better to handle the work than one that promiscuously tackles everything that comes along without consideration of its presumable value and practicability, as well as salability.

Qualifications for Running a Small Shop.—Not every man who has successfully managed a large production line is necessarily qualified to handle the peculiar undertakings and system or lack of system of some of the small shops. The very fact that a man has engaged in contract and special jobs indicates that he will be obliged to turn from one job to another at any hour of the day.

A man accustomed to lining up a production system and following it through does so according to some well-defined plan of the

plant as a whole, and under the system established there he routes his work and maintains the output of the production line. His business is routine in the sense that he manages the operations and controls the flow of work without delay in any one department or group of departments. He is usually well supplied with manufacturing equipment, tools, gages and, in general, everything that is essential to production. Also he will have assistants that know the routine of the business about as well as he himself does. Moreover, he has an opportunity to manufacture parts according to the best known methods and does not need to resort to makeshift devices for certain operations. His work is not constantly interrupted by the necessity for breaking into production in order to turn out a few special pieces for a hurried customer.

The job shop and contract shop, on the contrary, handle one thing after another with the most important thing coming first so far as it can be worked into the open machines with the available men. A large part of handling such a shop consists in knowing just where and when a much-wanted piece of work can be machined. Has he an 18-in. lathe open for a piece to be turned? Or if not, when can he get into such a machine for a job that the customer is waiting for? When will the miller or shaper be open for another piece of work? If Henry Jones is out sick for the day, who is available for the kind of work on which Henry is particularly useful?

Is the grinder going to be open for an hour's special job or will it be better to use a grinding attachment in the lathe? If the miller is on a job of jig boring, can he get into a shaper for a fairly good run of work, or has all the shaping capacity been tied up also for the time being? If there is a fairly long run of milling, is it long enough to justify purchase of special cutters, or will it be best with limited buying capacity to use simpler cutters now on hand and take more time for the work?

The small-shop manager knows, or should know, the peculiar and special abilities of his men, and he should know which to put on certain work if he wants that work in shortest time and with best quality of workmanship. Without reflection on any skilled man's capacity, some men turn most readily to certain classes of machines and types of work, whereas others have equal ability for getting out quickly and accurately another type of job.

Teamwork of a kind is important in the small shop. And teamwork between shop executive and workmen is of first importance. The manager must often use the craftsman's judgment and experience in determining just how it is best to proceed with a given job. This applies often to special tool work, such as the making of press tools. Often the man at the bench may have a better idea of the way to handle a die job than the shop foreman. And it is to the credit of all interested that much work of his kind in the small shop (and sometimes in the larger shop as well) is left in a liberal measure to the particular judgment and experience of certain highly skilled diemakers.

Large Customers and Small.—The small-shop manager has to discover early in his career that often the large buyer of contract work makes it possible for the smaller purchaser to have his work performed at a lower rate than would be the case if there were no large orders on the books. Sometimes the costs to small customers would be almost prohibitive for certain kinds of shop work if the purchases of larger customers did not make it possible for the shop to install the latest and most advantageous types of equipment.

In general, the small shop cannot equip itself properly for really economical operations, especially on production jobs, if it has depended solely upon very small orders where constant setup is required and many makeshifts resorted to in order to get the work out under any circumstances. Orders of important size must be on the books if the management is going to feel able to spend money liberally for special-purpose tools and equipment. This is the case with both shop and toolroom equipment. Large orders for this class of shop enable it to be adequately equipped. As a consequence the smaller customer reaps a real benefit from the fact that the larger buyer is also a customer of the same plant. The advantage of this situation is not entirely in lower costs to the customer but also in respect to a higher quality of work turned out on the superior equipment thus made available in the shop for all its customers.

It may be that an expensive special type of machine is desired by the shop management, and one good-sized contract may make it possible to buy that machine. Its advantages coupled with its accuracy of output will for years be of value to the shop and its clients, small as well as large, but without the business of

the latter, the shop would not have felt able to hazard the purchase.

The successful contract shop tries to build up a few active lines which will keep certain numbers of machines and their operators fairly steadily employed and which should go a long way toward meeting pay rolls and some of the other shop expenses. Idle time, when it does come, can be filled in with short-run jobs that are often too brief to justify setting up special machines for their performance.

Clean Shops.—Good housekeeping is as important in the shop as in the home, though it may not be judged by the same standards. Floors and windows can be kept reasonably clean, as well as the machines themselves. Lighting, heating, and ventilation are also important for comfort. And comfort means more and better work as well as more contented men and less labor turnover, which is more expensive than many realize.

It often pays to consider whims in the interest of harmony, which really means more production, unless they are too whimsical. One shop, for example, keeps a supply of floor boards, or gratings, for men "who can't work on a concrete floor." The boards are supplied without question, generally to new men only. As a rule they find their way back to the stock room in a few days or weeks, objections to the "hard concrete floor" having disappeared. When little troubles are taken care of promptly, big troubles are much less apt to develop.

Locker rooms and washrooms are too often neglected. No reasonable man expects high class hotel accommodations, but he has a right to expect cleanliness and convenience. Too great difference between facilities provided for office and shop workers leaves a bad taste and is resented, not without reason.

In some cases however, shopmen do not show their appreciation of first class accommodations, which presents quite a problem in discipline. Failure to help keep lockers, washrooms, and lunch rooms clean usually comes from a lack of home training, and tactful education is required. One superintendent used the plan of requiring the offender to clean up after hours any litter he had left or to pay someone else to do it. This worked effectively in most cases, but occasionally dismissal was the only way out.

One old timer in this shop, who belonged to a strong craft union, would get unruly at times. The superintendent would telephone the business agent, who was more than ordinarily level-headed, and he would come and straighten the old fellow out in short order. He was an old worker and a good one, and the super didn't want to turn him adrift. Not all business agents are as sensible or efficient, however, and the same can be said of management.

Mutual understanding of each other's problems and viewpoints will prevent much expensive argument and antagonism. With mutual confidence and respect, based on fair dealings by both sides, all concerned have much to gain and nothing to lose.

PHOTOGRAPHIC RECORDS OF SHOP METHODS

Some well-known shops employ a method of recording photographically the methods used on any unusual job that is likely to recur at some distant date when everyone has perhaps forgotten the exact method of handling the work through the plant or when the "old timers" who did the work have left the plant. In any event, such views of the job are useful for application to other pieces of work of somewhat similar nature, and they frequently impress customers as to the ability of the shop to handle their work.

As an illustration, an unusual valve casting with taper body may have to be machined internally to an exact size and angle of taper for a big plug which controls the flow of liquid. For a few castings of that kind no jig or fixture for holding is feasible, and some means must be provided on the casting itself to enable the shopmen to set up the work and set the tools on the vertical boring mill.

In one case of this kind extension lugs or pads were cast on the work at each end and these were turned off to represent a base bearing of the top and bottom of the taper valve plug. This allowed the casting to be faced at opposite ends with parallel cuts so that it could be set properly either end up. These extra feet or pads provided a means for setting the tools for turning the taper surfaces and for taking test measurements and checking the work diameter at top and bottom.

Similar pads were also cast inside the valve body to aid in setting boring tools to taper and to check diameters.

Much smaller work in turret lathes and engine lathes often has to be prepared in the casting by applying locating and holding

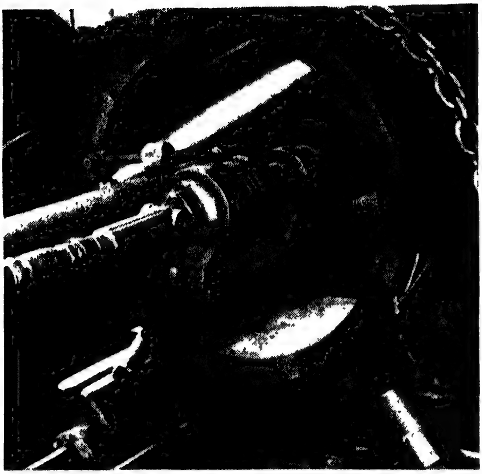

Fig. 1.—Special planetary grinding head for a large cylinder. This shows how the head was held and driven.

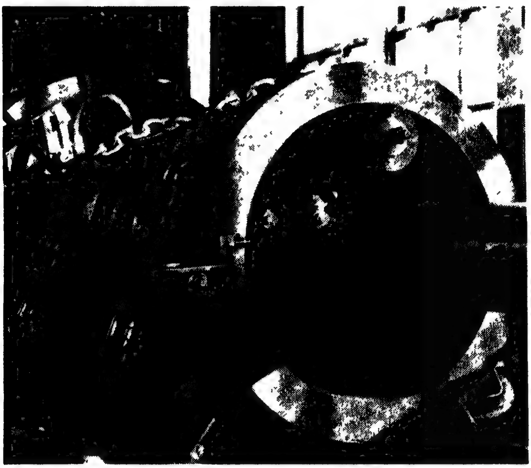

Fig. 2.—The wheel in contact with cylinder bore. This shows how the cylinder was held in the lathe carriage. The plug clamped against the face of the cylinder is the setting gage for the wheel. (*General Engineering & Dry Dock Co.*)

lugs or collars. While these are well-known devices, the handling of big special castings is not so common, so that a photographed

machine record of special ways of going at the job may come in handy on more than one occasion.

The illustrations, Figs, 1, 2, and 3, are typical of some of the jobs coming up occasionally in shops of various kinds. They are not all regular production jobs and, in fact, may seldom be repeated in exactly the same form, but for this reason there is an added advantage in having a photographic record as to just how their predecessors were taken care of. In most instances the photographic records will explain themselves, showing in

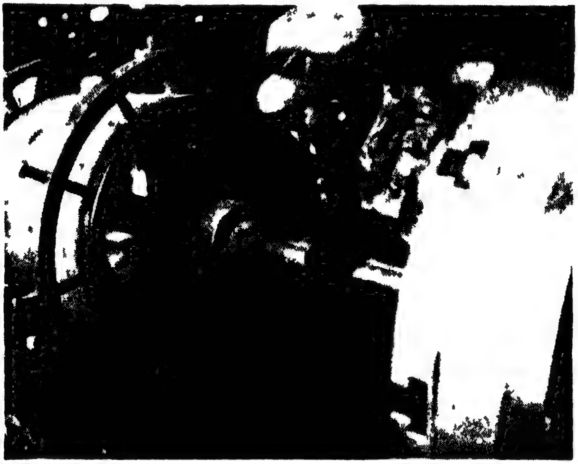

Fig. 3.—Simple fixture for holding cylinder bushing for boring in a lathe. A railroad shop job.

the cases of the heavy jobs just how struts and braces and clamps are used for securing the work in place.

Even the commonly used turret lathe requires a little consideration sometimes as to the best way to tackle a job of work. Any photographs of work of this sort are useful as suggestions. The railroad shop is particularly ingenious in handling awkward jobs. Usually only a few pieces of a kind come through at one time, and little in the way of special tools can be justified in such cases. Resort to practical means of doing work without special devices is therefore in order in such places, and the same is true of many job and specialty shops where one piece of work usually varies from the next.

CHAPTER 2

PLANNING A SHOP

Everyone starting a new shop, enlarging an old one, or moving into new quarters is confronted with the problem of shop planning. This planning may vary from the arranging of a few tools and machines in a small room, for a one- or two-man shop, to the laying out of a complete manufacturing establishment, but each is important in its own way. And there are no hard and fast rules, no standard pattern, that will be best in all cases. Each must be considered from the special conditions involved.

These conditions depend on whether the shop must be fitted into a room or building already erected or into a building designed and built to suit both the conditions of the land available and those of manufacturing after the shop has been built. Small-shop problems are more often those of fitting the necessary machinery and equipment into a building already erected. The choice of building to be rented or purchased may easily depend more on the availability of the space for the work to be done than on its exact location or other considerations.

In the case of new shop buildings it is a common mistake to be too greatly influenced by the cost of the land itself. Many have found to their sorrow that the cost of the land was not a large enough proportion of the expenses involved to allow it to become a dominating factor in deciding the location of the shop. Accessibility to supplies, ease of shipment, convenience of the employees, better fire protection, and a number of other conditions may easily be worth more than the saving of a few hundred, or even a few thousand, dollars in the purchase price of the land itself. It is, however, easily possible to pay too high a price for the desired location so that the investment becomes a factor in overhead that makes it difficult to compete with those in less expensive neighborhoods. But it is probable that more have made the mistake of saving money on the cost of the land and then have had the savings swallowed up by cartage, increased labor turnover, and other items. Added convenience, prestige,

and also personal satisfaction may well be within the extra price that it is necessary to pay. This matter of location should have very careful study, and false ideas of economy should not prevail.

In a similar way the rental price of a shop building or room should be carefully considered. Frills are seldom worth while, especially for the small shop. But here also, it is possible for injudicious economy to turn into expensive thrift.

In both renting shop space and erecting one's own plant, the management is faced with the choice of selecting a location in which there are other shops of the same kind or of going into a neighborhood where other industries prevail. Here again, there is no ironclad rule. Both policies have been followed with great success, and also with failures. Nearly every city has localities where many machine shops of a similar nature are very close together. The disadvantage of too much competition may be offset by the advantage of getting overflow work from the busy shops. Then too there is the advantage of having a greater variety of machine equipment available for the unusual job that comes along unexpectedly. Where one shop has a large planer, another a large lathe, while others have milling and grinding equipment, it is quite common for one shop to take the order and farm out the parts of it for which the other shops are best fitted. It is also common practice in some sections to rent out the use of special or unusual machines or tools to the other shops to be used by their own men.

Co-operative Shop Work.—In one case in the Midwest, three contracting machine builders merged their shops into a single unit, keeping the best equipment from each. Each concern remained independent as before. Each bid on any job that came within reach. The successful bidder had his work done in the combined shop, each of the three getting some return from the profit of the shop itself. This arrangement benefited all three concerns in several ways. Each shop had better equipment available than it would have had by itself; consequently, each had better facilities and could produce to better advantage. Each had a lower overhead as a result of the combination, which enabled them all to quote lower prices and so secure more work for the shop and for themselves.

Whether a number of small shops actually combine or not, it is a real advantage to be able to get work beyond the capacity of

one shop, done within a reasonable distance. In one Southern city the possession of a large wheel lathe and of a 300-ton hydraulic press brought this very small shop business from miles around, for no one else had machines of this kind. The lathe in question was too large to be housed with the other machines and stood outside the shop. When needed it was driven by backing a truck in position and driving a jackshaft from the rear axle of the truck. The press was used from the outside of the shop by sliding a wide door open so as to get at the press. Having special facilities frequently brings work from long distances for which more than the usual hourly rate can reasonably be charged. This is particularly true in the case of breakdown jobs where a whole plant may be standing idle because one machine is out of business. Here time is the most important factor, and every hour saved means many dollars to the customer.

THE SMALL SHOP

The term "small shop" is very elastic but is usually applied where not over 25 men are employed. In comparison with huge manufacturing plants, even a shop of 100 or more men might seem small; but it seems safe to consider 25 as a fair limit in most cases. In addition to the size of the shop, the matter of product is also important. For a small shop making a regular product may require a very different layout than a jobbing shop of the same size. Machine arrangement that might be the height of economy in one shop might not be desirable in another.

The Small Job Shop.—As machine arrangement is not and cannot be in the sequence of operations, as in manufacturing, the exact arrangement is much less important in the job shop. One never knows whether the first operation on a new job will be drilling, planing, turning, or milling. So it is not possible to say which machine should be nearest the point where the raw material comes into the shop. But, as the shop is small, there is very little time lost in either case, for distances are short between machines. For this reason, it is quite customary to group machines in the job shop, according to the kind of operation they perform. This usually puts all the lathes in one group, drilling and milling machines in their own group, and the planer or planers fairly convenient to the lathe group.

Even in small shops it is found helpful to have small drilling machines located at convenient points in addition to the regular drill-press group. Much time is saved by having a drill press near the job being done for the many odd jobs of drilling that come up in every shop. In the same way small tool-grinding stands for sharpening lathe tools and drills save time if properly located. This, of course, assumes that the shop has no regular toolmaker or tool sharpener. On the other hand, some small shops believe that a tool crib is necessary and economical.

Laying Out the Small Shop

Shop layout is a problem that has many angles. Some of these depend on the size of the shop and the kind of work that predominates in its activities. If the shop manufactures any article in large quantities, no matter how small the article may be, there are few cases where line production is not advisable. This arrangement not only saves time and labor in handling material, even though it be light, but economizes floor space and helps in assembly.

If, however, the shop is largely occupied with jobbing work, tool layout and other conditions may be entirely different.

Where the work is light, as in most tool and die work, and in small contract work, several small-shop owners state that shop layout is of minor importance. Benches, they feel, should be placed next to the wall containing windows and the machines so located as to give as much natural light as possible. But the bench arrangement, or position, is open to differences of opinion.

One well-known toolmaker insists that the benches run along, or parallel to, the wall so that the men face the window. Others prefer short benches that run at right angles to the wall so that the light from the window comes from the side. Here again, some want the light from the right, others from the left, this applying to single benches. One shop uses double benches, where two men face each other. In this case right- or left-hand light can be given to those who prefer it.

Going back to machine location we find several factors to be considered. If the shop is in a loft building, as often happens in the city, floor load is an important consideration. This means that heavy machines must be placed near walls or near the col-

umns that support the flooring. For this reason we sometimes find punch presses or other heavy machines scattered instead of being grouped together as would normally be the case.

Even this, however, may not be such a handicap as it appears, since there is seldom a flow of work from one machine to another in this kind of a shop. In fact the sequence of operations may vary widely with almost any job that comes in. While practically all jobs require drilling, turning, and milling, as well as bench work, the sequence of operations varies. The work may go to the lathe or the drilling machine first. And in the average small shop the floor area is too small to make the handling of the material much of a problem.

Avoiding Unnecessary Handling.—When a shop of any kind deals with heavy castings or other materials, it is, of course, important that the machines likely to handle the work first be located near the point where it is received. In such a case it would probably be advisable to locate all the heavy machine tools as near the receiving end of the shop as possible. This would reduce the amount of handling of heavy pieces, and this is more important than the grouping of all machines of a kind, as is the usual practice.

When the machine equipment is comparatively light, as is usually the case, grouping by class of machine is perhaps the logical method. In some cases the small bench lathes or bench millers (for some of these are found in small shops) are placed on the benches near the windows. In other shops they take their place with the regular lathe or milling group.

While machine location in the tool or job shop does not seem to be so important as might be supposed, the position of the tool crib may well be considered. In most shops the tool crib is tucked away in a corner on one side, or one end, of the room instead of being in the center. Yet at, or near, the center seems to have advantages. For while the flow of material may not be particularly important in the average small shop, the total daily travel of men to and from the toolroom may come nearer to being a marathon than we realize. Then too the light in the center of the shop is seldom as good as might be desired, while the poorer light may be ample for the tool crib. Or if artificial light is necessary, it is not so important or costly as for machine illumination.

Machine location in any shop depends on whether we must fit the machine equipment into existing floor space, which is not the ideal condition, or build a new shop that can be laid out to fit the work and the machines. Even with a new shop, there are limitations in the shape of the available land or in the effect of other buildings on the light in the new shop.

Single- or Multistory Shops.—When shops have to be fitted into old buildings, layout becomes a matter of arranging machines to utilize the space available to the best advantage. But in the case of a new building one is confronted with the decision between a single-story building or a multistory building, in addition to the way in which the machinery and other equipment is to be laid out.

For the small shop the single-floor plan has many advantages if the land is available. There are also many large shops built on the single-story plan. But for the large shop the distance that material must be moved and the distance that must be traveled by executives are both problems to be considered.

With shops from 500 to 1500 ft. long this becomes a real problem. With a two-story shop the length can be halved, and by going out from the office on one floor and returning on the other, the plant is covered with half the travel. Offices in the center of the plant usually reduce the travel of executives to a marked degree.

Multistory shops have advantages in some kinds of manufacturing where, as in automobile building, the body can be dropped on the chassis from the second story. With the body and frame built as a unit, as is the trend, this advantage disappears.

Handling materials in a multistory shop introduces special problems, such as the location and use of elevators. It seems to be generally felt that where elevators are used, they should be on the outside of the building proper. This leaves the floor space clear for the best arrangement of machines to secure a free and unobstructed flow of work through the shop. For the same reason some shops are built with toolrooms, washrooms, and all services of this kind outside the main walls. This makes it possible to rearrange the shop layout at any time without diverting the flow of material around departments that project into the main shop building.

The selection of elevators, conveyors, or other handling apparatus must be considered in the light both of present requirements and of changes that are likely to be made later. Conveyors are now made in so many forms and have such a variety of uses that each application should be carefully studied. The various kinds of conveyors will be shown in a number of applications. From these each shop can select those best adapted to its particular needs.

A Typical Small-shop Layout

Machine location has a lot to do with the cost of handling work in the small shop just as it has in the large plant. While the flow of work is not so important as in large shops, because the distances moved are short, the small losses of time add up to appreciable totals.

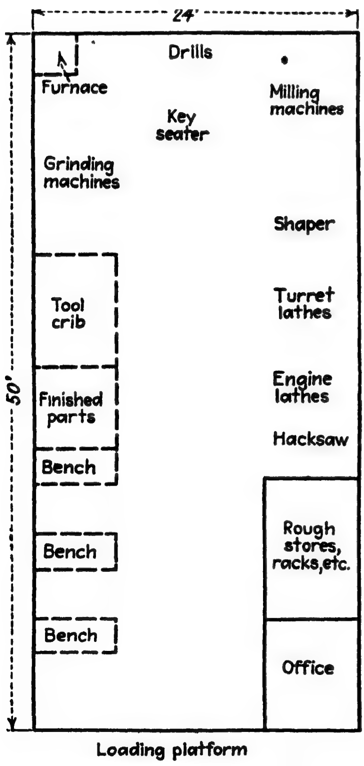

Fig. 4.—Small shop layout.

The average small shop has no regular product but must handle a variety of work from week to week. The layout problem involves the average work that is likely to come along. Fortunately, however, the decisions need not be final as the machines can usually be moved to new locations without much difficulty.

Figure 4 shows how one experienced shop manager laid out a small shop for a friend who was starting in business. The room was 24 × 50 ft. and had windows on all four sides—but there would probably have been few changes regardless of the windows since the space had to be used.

This layout is based on the plan of handling the rough stock, such as castings, bar steel, and the like, directly from the loading

platform to a small store room fitted with racks. From here it goes to the power hacksaw, if cutting off is necessary. The other tools are arranged with the idea that lathe work usually follows cutting-off, although the lathes can be passed by for the shaper, the milling machine, or the drills, if occasion demands. A hardening furnace is in the far corner to be as much out of the way as possible.

The tool crib is in about the center of the opposite wall so as to be convenient to all men at machines. A small place is provided for finished parts, beside the tool crib and next to the benches used for assembling the work. The benches run at right angles to the wall and the windows, both for better light on the work and to give each man a separate place to work. If it is thought best to have the light come at the man's right instead of the left, the benches can be moved so that the first bench is next to the front wall and the last man stands with his back to the finished-parts room.

One suggested change is to put the drills between the hacksaws and the lathes, moving the milling machines along the back walls, on the theory that drilling is as likely to be the first operation as turning. Another suggestion is to put the drills between the lathes and the shaper.

A Compact Job Shop

A very compact shop was found in a Southern city. There are few shops like this one where twelve machines and a hydraulic press are put in a space of 19 × 32 ft. In addition, there are an electric welding outfit and oxyacetylene equipment. None of the equipment is new, as indicated by the Pease planer and the Steptoe shaper. It is the practice of this shop, however, to overhaul every machine thoroughly once a year and to give it a coat of paint.

The main door is the one shown near the desk in Fig. 5. Diagonally opposite is a wide sliding door which opens to the 300-ton hydraulic press. All the work on this press is done with the door open, both for access to the press and to give room to work. The shop can also be entered by passing the corner of the press. This press, incidentally, is the only one for miles around, which ensures a fairly steady run of work that requires press fits.

Such jobs include tractors, packing-house machinery, road machinery, and similar work—frequently an emergency job.

The "office" is small and is situated in the corner by the small door but answers every purpose. It has ample room for files against the end wall. Along the same wall is a stack of bins for holding various materials such as screws, bolts, and the like, while the open shelves beyond hold castings for bushings and other parts that go to make up the work of a job shop.

This shop was originally laid out for line-shaft drive arranged to avoid crossed belts. Since then each machine has been

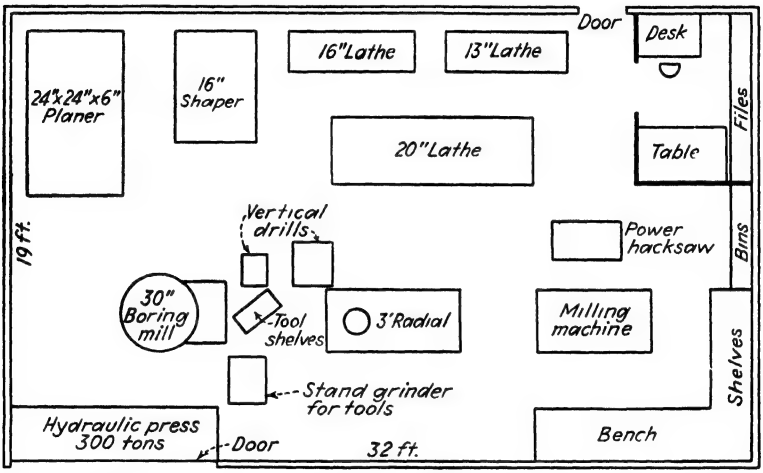

FIG. 5.—Compact arrangement for a small shop in a warm climate.

motorized, using ingenious supports of various types to hold the motor either above or below the head of the machine.

The building is made of corrugated steel, both sides and roof. An opening is left between the sides and roof for ventilation, this space being closed by a storm curtain when necessary.

They have since moved into a larger shop.

UNIT DEPARTMENT OF A LARGE PLANT

Link Belt Co.—The reducing-gear mechanism known as the "P.I.V." is made by the Link Belt Co. in a special department that was laid out for this purpose. The floor plan, or layout, is seen in Fig. 6.

The castings come into the building from the lower left-hand corner where two surface grinders, a Gardner and a Diamond,

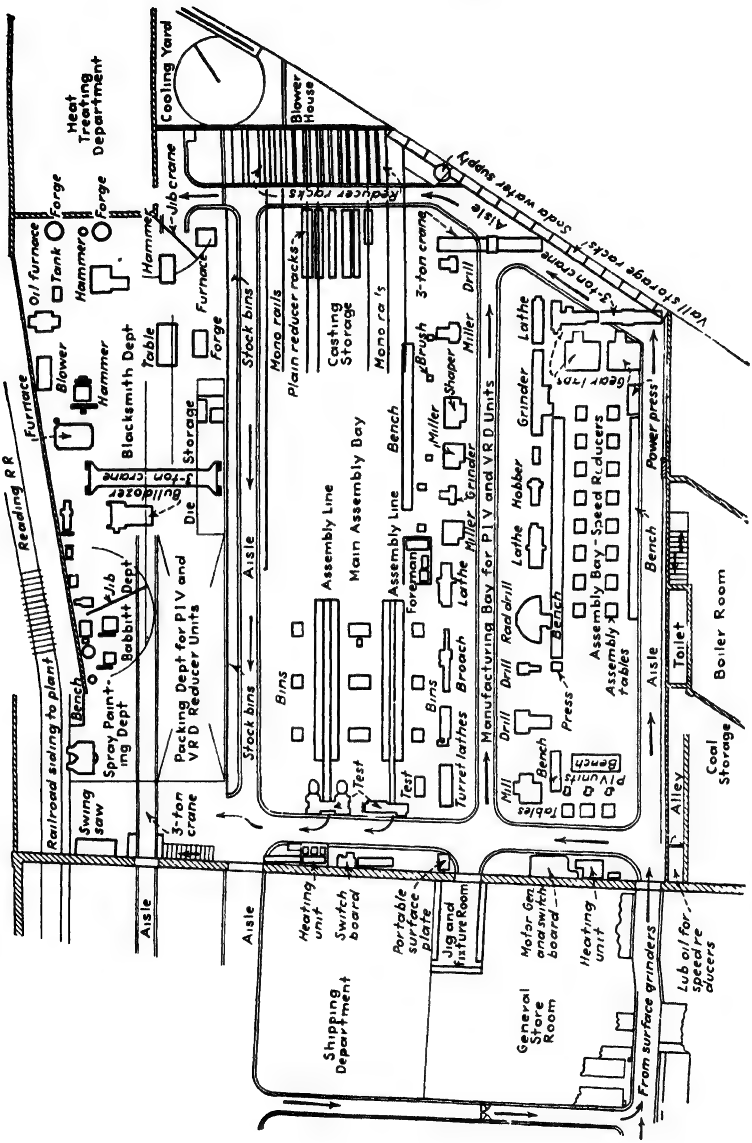

FIG 6 — Link-Belt shop for power transmissions

grind such surfaces as they can handle. Then before going into the main building, the castings receive a coat of paint, for with the castings ground and painted, there is little chance for grit and dust to reach the precision machinery used in finishing these parts.

As the castings come into the shop and go up the aisle at the left, they pass a general storeroom where all supplies are kept, including about 600 electric motors. This extensive supply permits quick shipment of a variety of transmissions. In one corner of the storeroom is the jig and fixture storage, which can be conveniently reached from the machine department. Enclosed wall storage racks at the opposite end of the shop are used to store a wide variety of cutters and other tools.

The general plan followed is to use the center aisle of the shop for machining the P.I.V. gear units which are then taken to the main assembly bay and stored. Castings are stored at one end of this bay on racks designed for the purpose. Against the far wall is a row of stock bins to carry the smaller parts.

The bay on the opposite side of the center aisle is used for assembling speed reducers. The heat-treating department is located just off one corner of the P.I.V. department proper, where it is conveniently near to handle the work rapidly, while still sufficiently isolated to separate it from the machining operations.

Aisle Markings.—It will be noted on the layout that all aisles are plainly marked with double paint lines. This keeps them clear to ensure uninterrupted transportation of the work through the shop at all times.

The view shown of the machining bay is looking from the final operation toward the first operation. In general the machines are placed so the work goes progressively from one to the next, with the castings and heavier parts on one side, and the wheel faces and smaller parts on the other. Complete crane service is supplemented by the use of electric trucks.

The same smooth work flow is continued through the assembly operation. Because of the wide variety of sizes, speed ranges, and gear reductions, it is uneconomic to stock finished units. However, the parts are stocked, and the assembly department is planned particularly to reduce the time between receipt of the order and shipping of the units. For this purpose assembly

operations are made progressive, and special care is taken to bring the parts close to the operators.

One way of doing this is by the use of some intermediate storage racks. When the foreman receives the bill of material for an order, he has one of his men collect all the parts needed from the main storage bins which may be seen in the illustration and transfer them to the intermediate bins which are located between the two rows of work benches. This arrangement means that the man actually at work on the assembly operation does not have to look around the shop to get the parts he needs or to select the particular sizes he wants from a large bin. Everything that goes with the order he is working on is centered at one point.

A gravity roller table is used for the smaller P.I.V. units. Another table is used for the heavier units, and over this extend two chain hoist monorails which permit turning over the casting in order to assemble the parts. A small drill press between the aisles serves for minor fitting operations. At the end of the bay, between the two rows of tables, are the testing fixtures in which the units are given a power load before shipment. Because of the convenient arrangement for assembly operation and the proximity of the inventory of stock parts, it is possible to ship P.I.V. units in from one to five days from receipt of the order.

It will be noted from the plan view that the spray-painting department and the packing department are just off the end of the shop where the units leave the testing machines. These are so located that even up to the time of shipment a work flow is arranged to avoid backtracking and needless handling.

Perhaps the only thing that remains to be said is that a complete new heating plant has been installed, so that uniform control and circulation of the air in this department is maintained at all times. This additional precaution for the workers' comfort combined with cleanliness and convenience of layout induces careful and efficient workmanship.

A Tractor Plant and Its Equipment

Allis-Chalmers Company.—Selecting suitable equipment and arranging it in the shop so as to secure maximum efficiency in production is a vital problem. No rules can be laid down that

Table 1.—Equipment Analysis

Gear Department

No	Size and make	Operations
	Drilling units	
2	No. 4 Colburn	$2\frac{3}{8}$- and $1\frac{13}{16}$-in holes in hubs of differential bevel and reverse idler gears, respectively
	Broaching	
1	Oil gear horizontal broach	Clear bores and cut keyway in fixed gears
1	American vertical broach	Cut splines in sliding gears in transmission, and in differential bevel gears
1	"General" arbor press	Mounting and dismounting gear blanks on splined arbors
	Turning units	
2	No 2L Gisholt turrets	Monarch tractor bevel gears
1	No. 3L Gisholt turrets	
2	No 3A Warner and Swasey turrets	Large sprockets for Monarch tractors
1	No 4A Warner and Swasey turrets	Large bevel gear for Monarch
1	No 2A Warner and Swasey turrets	Boring and turning combination spur and bevel, first reduction gear—Model U
2	No 4F Fastermatics (Foster) (Hannifin pneumatic chuck, Oil-gear feed on turret slide and cross-slides)	Differential ring gears (United) (A) turn outside diameter and face both sides, (B) bore and put in clearance groove
4	Hartness 2-spindle flat turret lathes	United tractor gears (A) face and bore sliding gears, (B) face, and finish bore differential bevel pinions (C) rebore, face, finish-bore, and ream large differential bevels, (D) bore, turn, and thread cast-iron differential carrier adjusting nuts
7	12 × 6 in. LeBlond multicut lathes	Face and turn sliding gears and bevel gears, mounted on splined arbors carried on centers, turn power take-off cross shaft with integral bevel pinion, spline shaft turning, axle turning
3	12 × 7 in LeBlond multicut lathes	
1	16 × 7 in. LeBlond multicut lathes	
1	17 × 8 in. LeBlond heavy-duty engine lathe	Face differential pinions carried on splined arbor, general work on gears and axles

No	Size and make	Operations
1	No 6 Warner and Swasey turret lathe	Drill and tap ends of power take-off cross shaft
1	Duplex Cincinnati Lincoln-type miller	Face ends of cross-shaft forgings
1	Sundstrand centering machine	Center ends of above
1	"General" flexible power press	Straighten above on centers
1	10 × 36 in Landis cylindrical grinder	Rough grind seats on pulley pinion shafts, bevel gear shafts, and rear axles for fitting collar for mounting in gear-cutting machines
1	Carlton 3-ft radial	Miscellaneous drilling
	Gear-cutting machine group	
1	Large Newark gear cutter	Large sprockets for Monarch tractors
3	No 17 Barber-Colman hobbers	(A) ring gears, (B) spur gears for Monarch tractor
2	No 36HS Gould and Eberhardt automatic gear hobbers	Monarch spur gears
2	No 60B Gould and Eberhardt bevel gear cutters	(A) single-spindle unit for large bevel gears for Monarch tractor (B) three-spindle unit for medium-size bevel pinions for both models
2	No. 36 BM Gould and Eberhardt automatic gear cutters (2 spindle)	(A) rough-cutting differential bevel pinions, (B) cut bevel gear of first reduction unit (combination spur and bevel)
3	No 16 Barber-Colman hobbers	Spur gears for Model U tractors
5	No. 12 Barber-Colman hobbers	Splines in transmission countershaft and on rear axle halves
5	No 12 Gleason bevel gear-finishing machines	Bevel gears and pinions for Model U and Monarch
2	No 8 Gleason high-speed bevel-pinion finishers	Differential bevel pinions both models
1	18-in Gleason bevel-gear tester	Inspect
1	No 7A Fellows high-speed gear shaper (510–1620 strokes per minute)	Cut internal teeth on clutch gear

TABLE 1.—EQUIPMENT ANALYSIS.—(*Continued*)

No.	Size and make	Operations	No.	Size and make	Operations
	Gear-cutting machine group—(*Continued*)		1	No. 33 Kempsmith miller	Miscellaneous milling operations
2	No. 6A Fellows shapers	(*A*) internal teeth on large Monarch clutch gear; (*B*) couplings halves for Monarch tractor	2	No. 2 Milwaukee millers. One with indexing fixture	(*A*) Mill clutch on spur pinion; (*B*) miscellaneous milling operations
1	No. 2 Milwaukee miller, duplex cutters	Mill clutch teeth in hub of clutch-shaft pinion	4	No. 2F Fastermatics (Foster)	(*A*) Cast-iron parts; (*B*) forged-steel differential hubs
1	No. 33 Kempsmith miller	Cut keyway on transmission jackshaft	1	No 3F Fastermatics	
1	14-in. Leland-Gifford 2-spindle drill	Drill and burr oil holes in gear rims	1	No. 1F Fastermatic (Special tooling)	Clutch bracket and clutch shifter yoke
2	Peerless chamfering machines (pneumatic chucks)	Round teeth of sliding gears	1	No. 3F Fastermatic	Transmission case head only
1	Lees-Bradner thread miller	Cut threads on rear axles	1	No. 3F Fastermatic without turret, but with single tool carried in turret position, with cam control on overarm	Power take-off pulley
1	Adams gear tester	Inspect spur gears			
1	Taylor and Fenn spline miller	Spline work on shafts			
	Screw machines		1	No. 1L Gisholt turret lathe	Turn and face differential bearing holders
1	⅞-in. 4-spindle Cone automatic	Small parts, differential studs, etc.	1	W. F. & J. Barnes special boring unit	(*A*) rough- and finish-bore, ream, and thread transmission-case head; (*B*) drill and finish-ream three holes in head
1	1¼-in. 4-spindle Cone automatic				
1	2¼-in 4-spindle Cone automatic				
1	⅞-in Cleveland automatic		2	Fox adjustable, multiple-spindle drills, hydraulic feed	(*A*) drill differential hubs; (*B*) drill large Monarch sprockets, etc
1	1½-in. Cleveland automatic				
1	2½-in Cleveland automatic		1	3-ft Carlton radial	Drill and tap hole in transmission cover; miscellaneous
1	4½-in Cleveland automatic				
1	4¼-in. Gridley automatic		1	5-ft Western radial	Drilling, tapping, spot-facing
1	3-unit Kingsbury drill	Drill cotter-pin holes in differential studs and clamp bolts, etc.	1	4-spindle Leland-Gifford drill	Miscellaneous operations
			1	No. 6 Gardiner disk grinder with fixtures on swing arms	Face-grind steering gear bracket, air cleaner base, exhaust elbow, etc.
1	3-unit H & G threading head	Threading above parts, etc.			
1	Kempsmith hand miller	Mill keyway in above parts	1	36-in. Blanchard surface grinder	Small, flat work
1	Colt Autosan washer for small gears and screw-machine products			Gear grinding	
			3	No. 72A-3 Heald internal grinders, pneumatic chucks	Grind internal bores of sliding gears
	General manufacturing section				
1	W. F. & J. Barnes Special 4-way turning-unit	Turn and center differential spider	2	Large Heald internal grinders	Grind Monarch and Model U ring gears internally
2	4-spindle Leland-Gifford drills	Drill three holes in radius rod (wishbone) and tap one, etc.	1	6 × 30-in. Landis cylindrical grinder	Shaft work, transmission countershafts, power take-off, constant-mesh gear
1	1-spindle Leland-Gifford drill	Drill shifter rod (transmission)	1	14 × 36-in Cincinnati cylindrical grinder	
1	Kempsmith hand miller	Mill keyway in steering-spindle arm	1	10 × 48-in. Landis grinder	Grind rear axles, etc.

Table 1.—Equipment Analysis.—(*Continued*)

No.	Size and make	Operations
	Rear-axle housing	
1	Special Ingersoll boring and milling machine	Face and bore rear end, bore and face front end
1	Special Ingersoll boring machine	Bore main-bearing and differential-bearing carrier seats
1	Greenlee hydraulic drilling unit, opposed heads	Drill 31 holes front and back
1	Greenlee 3-way hydraulic drilling unit	Drill 10 holes for axle-cover plates, and 3 in top
2	Greenlee opposed-head, multiple-spindle tapping units	Tap above holes
	Transmission case	
1	42 × 28 in. × 8 ft. Ingersoll planer-type miller, screw feed, 6 cutters	Mill two ends and cover
1	30 × 48 in. Ingersoll duplex miller, hydraulic feed, 3 cutters	Mill pads on side
1	Special Ingersoll opposed-head boring machine, Oil-gear feed	Bore and face large internal diameters
1	Special Ingersoll 3-way boring unit with tapping attachment	Cross-bore three 6-in. holes; bore, ream, and tap one 5½-in. hole
1	Greenlee 3-way, multiple spindle drilling unit, Oilgear feed	Drill 42 holes in ends and one side of case
1	Greenlee 3-way, multiple-spindle tapping unit (lead screw)	Tap 24 holes drilled as above
1	Greenlee opposed-head, multiple-spindle drilling unit (Oilgear)	Drill 41 holes in sides of case
1	Greenlee opposed-head multiple-spindle tapping unit (lead screw)	Tap 24 holes as of above and ream 3
1	Niagara washer	Wash castings
	Front-axle and steering knuckle	
1	No. 33 Kempsmith miller, indexing fixture	Straddle-mill both ends of front axles
1	Special W.F. & J. Barnes machine, two 20-in. vertical single-purpose production drills and one 5-spindle horizontal unit head with hydraulic feed	Drill 5 holes in side of axle, and drill and ream kingpin holes

No.	Size and make	Operations
1	No. 3 Rigidmil (Sundstrand)	Straddle-mill steering-knuckle yokes
1	Special W.F & J. Barnes horizontal, opposed-head drilling unit with rotary fixture	Drill, ream, and finish-ream kingpin holes in knuckle
1	12 × 7 in. LeBlond Multi-cut lathe	Turn 4 diameters and shoulders on wheel spindle of knuckle
1	No 9 Natco-Minster drill, single spindle	Drill hole in knuckle for steering arm
2	2-spindle Leland-Gifford drill	Drill cotter-pin hole and oil hole in knuckle
1	Cincinnati high-speed tapper	Tap oil-fitting hole
1	14 × 18 in. Cincinnati cylindrical grinder	Grind bearing seats on wheel spindle
1	8-ton "General" flexible power press	Broach keyway in steering-arm hole; assemble gears on shafts, etc.
1	4-ton "General" flexible power pre[illegible]	Press on bearing races, assemble small bush[illegible] etc.
1	[illegible]	[illegible], including [illegible]ing of shifter rod and forming ball at other end
1	W F. & J. Barnes Special 4-way drilling unit with three sets of tools	Drill, ream, and finish-ream 4 bearing holes in cast-iron differential carrier
1	Reichert spot-welder	Weld fenders
1	Special Stolp forming and seaming machine	Form and bead joint of gasoline tank from sheet stock
1	American Can Co. heading unit	Bead and roll in heads of gasoline tank
1	De Vilbiss paint-spraying booth and dryer oven with conveyor	Paint and dry tractor unit
	Toolroom	
1	Gleason gear-cutter tooth grinder	
2	Oliver drill grinders	
1	14-in Cincinnati reamer grinder	Keep all tools in sharpened condition
1	Barber-Colman hob grinder	
1	Internal cutter grinder	

Note: All Fastermatics are equipped with Oilgear feed on the cross slides and turret, Hannifin pneumatic chucks, and Allis-Chalmers Texrope drives.

will fit all cases, but a few examples from successful practice will be of assistance as a guide in similar lines.

The shop layout shown in Fig. 7 is the tractor department of the Allis-Chalmers Company in 1930. The tractor weighed

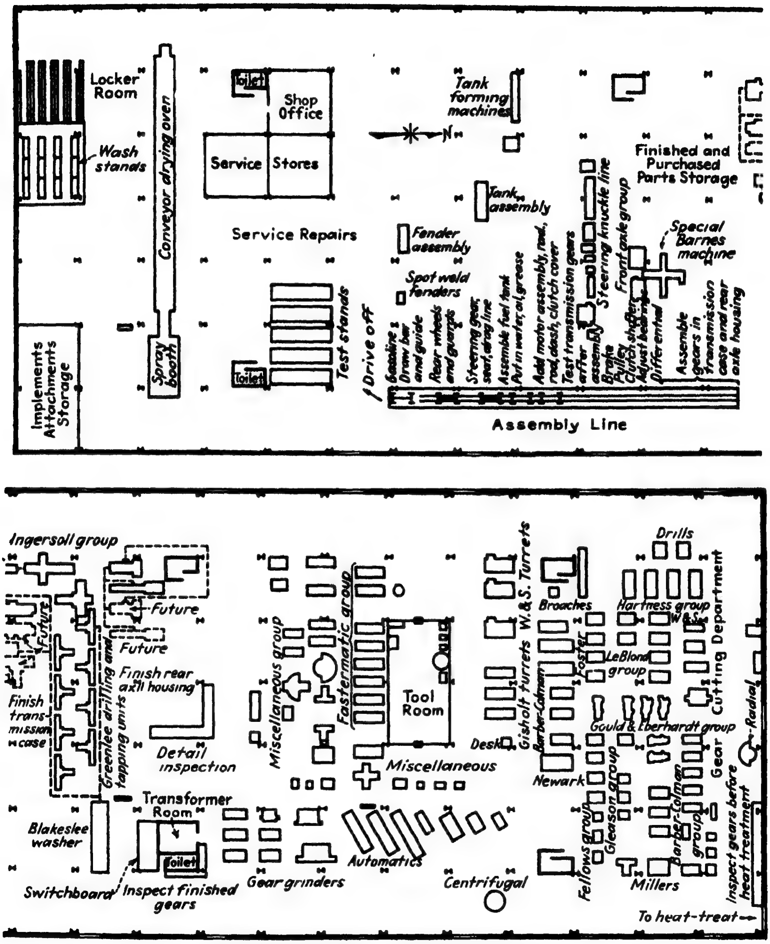

Fig. 7.—Layout of large tractor plant.

about 4700 lb. and had a rating of 35 hp. The plant was laid out for 50 tractors per day with provision for expansion by the introduction of additional machines in certain key positions. In addition to the 160 machine tools purchased, there was a heat-

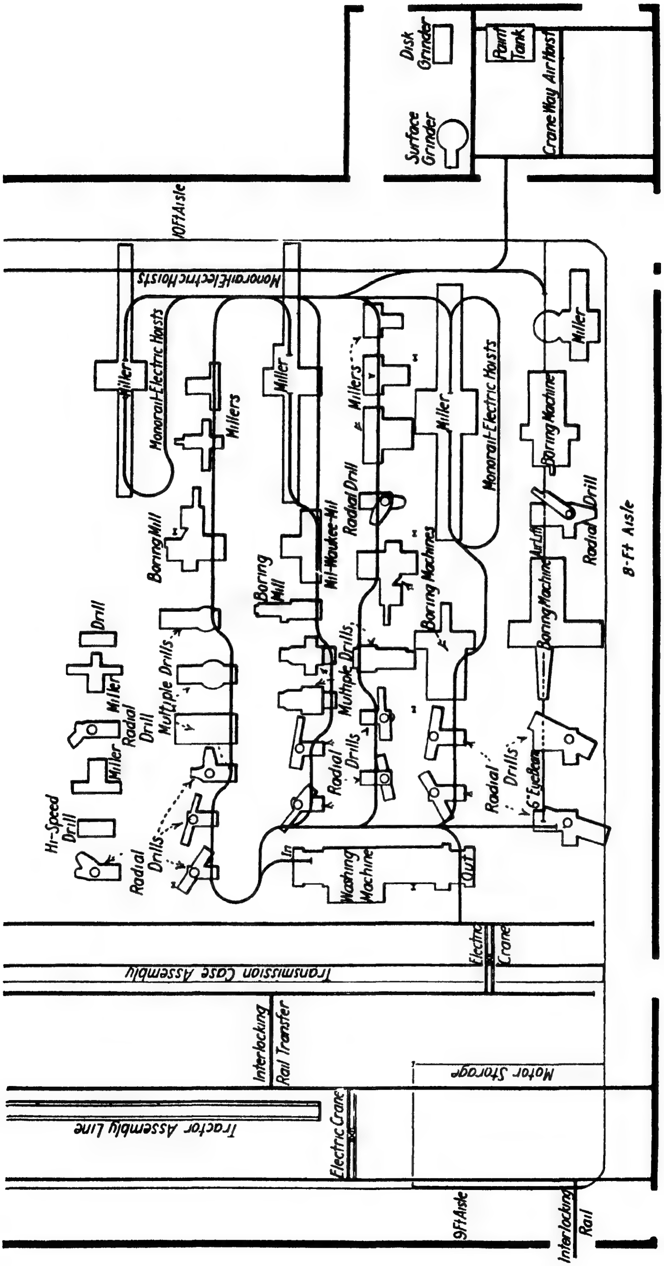

FIG. 8.—Small tractor-plant layout.

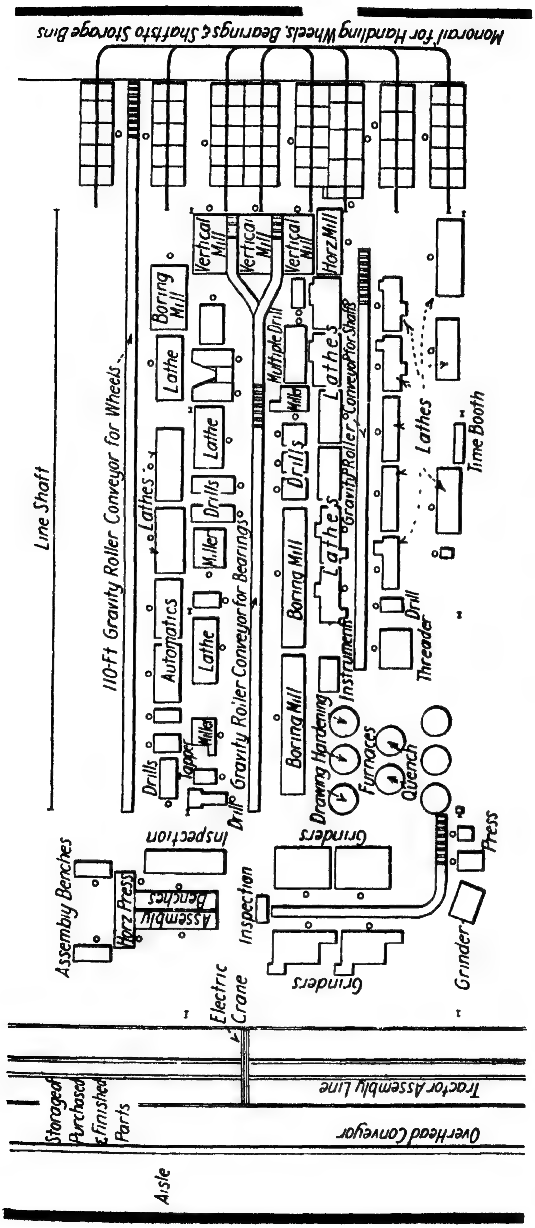

Fig. 9.—Departmental layout.

treating department, housed in another building, and an additional department created in the foundry. The layout and tool list include only the machine shop. As will be seen, the equipment does not include the motors, which are purchased. A study of the equipment selected will be very helpful in a number of machining operations, even though they bear no resemblance to tractors. The machines are listed in detail together with the work they perform. Although personal preference or other conditions might affect the selection of the machines, the list given cannot fail to be of value as a general guide in a similar situation.

Another Tractor Plant Layout.—In Fig. 8 is shown the layout for a small continuous-production plant, the Cleveland Tractor Co., which builds tractors of the creeper type. It shows the department making transmission cases. The cases are first dipped in paint and come in from the small room at the lower right-hand corner. They go to the various machines, beginning with the milling machine. The parts move along the lines shown until they reach the upper end of the washing machine. After coming through the washer, they go to the transmission-case assembly line at the left and, when assembled, to the tractor assembly line to the left of that.

The layout for the department for machining the shafts, wheels, and bearings is seen in Fig. 9. The parts come out of the storage bins at the right and feed down the different lines shown. The three gravity conveyors carry the parts from machine to machine. The inspection benches and the assembly benches are shown at the left. From here the assembled units go to the tractor assembly line at the left and there become part of the completed tractor. At the end of the assembly line the tractor receives gas, oil, and water, the engine is started, and the tractor is tested under its own power.

Narrow Aisles Save Time

The old line shaft necessitated laying out the machines in rows parallel with the shaft. And much of this has remained, even though the line shaft has disappeared. Wide aisles between two rows of machines have been common for many years. The Ford Highland Park plant, which has since given way to the Rouge River plant, was one of the first to eliminate nearly all aisles and

to group machines closely, considering only the prevention of waste movements between machines. This is now becoming common practice in large plants, although many plants still retain the old style.

Two examples of this come from the Cadillac plant, one showing the change in the connecting-rod line and the other in another

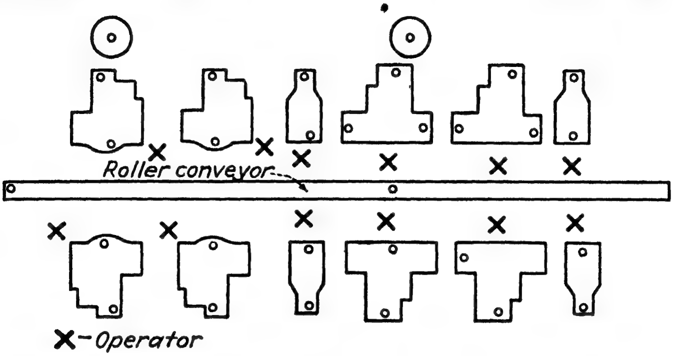

FIG. 10.—Old Cadillac layout.

department where the change is even more striking. Figure 10 shows the old layout with the conveyor running between the two lines of machines and with an operator for each machine. By abandoning the wide aisle and rearranging the same machines,

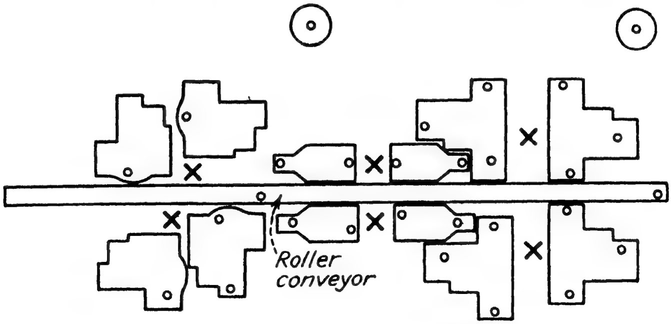

FIG. 11.—Narrowing the aisle.

as in Fig. 11, less floor space is used, and 6 men now handle the 12 machines. There is a slight loss in production per machine, but this is balanced by a 40 per cent reduction in direct labor cost.

A more striking example is seen in Figs. 12 and 13, which show a department handling a piece weighing about 16 lb. Figure 12

shows the old layout, the movement of the work being shown by the arrows. The amount of space occupied can be figured from the scale of feet in the plan. The machine equipment of this department is also of interest and is given in the list. As rear-

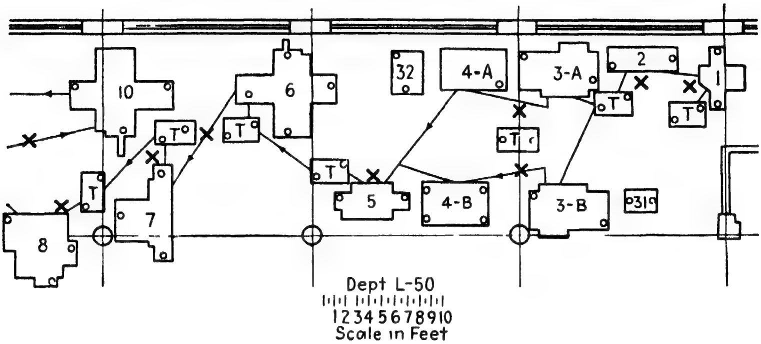

FIG. 12.—Another example of old layout.

ranged, all aisles are eliminated; chutes are provided in some cases to reduce the travel of the work and of the men. In the case of machines 6 and 10, the apparent backtracking is to enable one man to run both machines. The number of men has been reduced

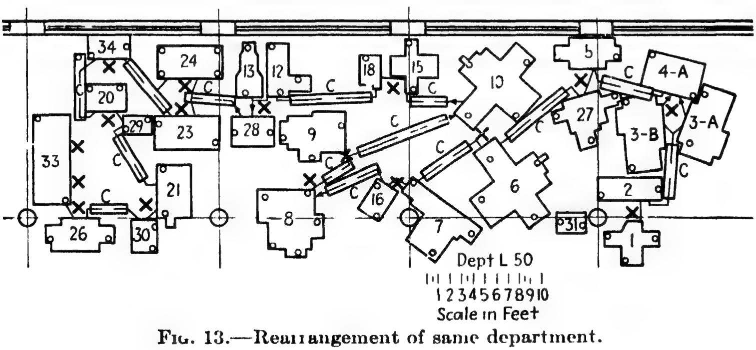

FIG. 13.—Rearrangement of same department.

from 27 to 17, using fewer machines than before, and the floor space has been reduced nearly 50 per cent.

Chutes Replace Trucks.—It will be noted that the 10 trucks shown in the old layout have been replaced by chutes leading from one machine to another. One chute, for example, feeds from the centering machine (2) to the two Lo-Swing lathes

(3*A*) and (3*B*). Lathe (4*A*) handles work from both these machines. The work then moves by chute to the Norton grinder (5). One operator handles the three Lo-Swing lathes. Another operator runs the two drill presses (12 and 13) and the thread miller (28), the chute from here feeding both the Bryant grinders (23 and 24). Comparing the list of machines in the original lineup with those shown in Fig. 13 reveals that 8 were eliminated by the rearrangement, in addition to the 10 trucks.

Key to Machines, Figs. 12 and 13

1. Brown & Sharpe milling machine.
2. Centering machine.
3*A*. Model R Lo-Swing lathe.
3*B*. Model R Lo-Swing lathe.
4*A*. Lo-Swing lathe.
4*B*. Lo-Swing lathe.
5. Norton grinder.
6. 48-in. Hydromatic miller.
7. Cincinnati miller.
8. 50-H Baker drill press.
9. 50-H Baker drill press.
10. 48-in. Hydromatic miller.
11. 48-in. Hydromatic miller.
12. Baker drill press.
13. 24-in. Cincinnati drill press.
14. Edlund drill press.
15. No. 2 Cincinnati miller.
16. Single-spindle drill press.
17. Whitney hand mill.
18. Whitney hand mill.
19. Whitney hand mill.
20. Taft-Pierce thread miller.
21. Lees Bradner thread miller.
22. Lees Bradner thread miller.
23. Bryant grinder.
24. Bryant grinder.
25. Norton grinder.
26. Norton grinder.
27. Rockford Rigidmill.
28. Taft-Pierce thread miller.
29. Avey drill press.
30. 2-spindle Edlund drill press.
31. Snagging grinder.
32. Wet grinder.
33. Bench.
34. Bench.

T. Hand truck.
C. Chute.

Typical Machine Line for Automobile Cylinders.—Figure 14 shows a typical line-up of machine tools for machining an 8-cylinder block in a modern automobile plant. This is a line-up from the Nash plant, but, with a few exceptions, it will be found in other plants with a similar output. The speeds and feeds used on the rather hard iron in the cylinder blocks make it necessary to use carbide tools, for even high-speed tools have a short life. High-speed cutters are used in such low-duty jobs as milling the locating pad and finishing the ends of the main bearings by

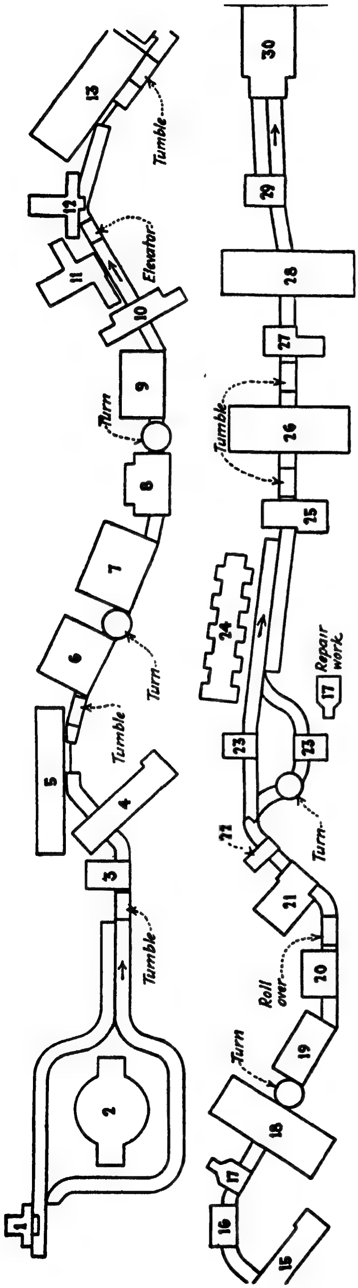

FIG. 14.—Layout for automobile cylinders.

straddle milling. Cam bearings are also faced with high-speed cutters.

The machine layout and the list of machines in the line tell a fairly complete story without any specific explanation.

AIRPLANE MACHINE SHOPS

Navy Yard Shop.—Laid out to give a capacity of 10 per cent of the Navy's airplane engines, this plant at the Philadelphia Navy Yard is a good example of layout and equipment. It has a capacity of 25 engines per week. Machines were selected with a view to operation by the average mechanic, rather than by an expert, in order to help keep employment at a fairly constant level during normal times when only three or four engines per week are being built.

The shop is departmentalized according to engine parts and the materials being used, one side being reserved for ferrous metals and the other for non-ferrous. In general, it is intended to complete each part of the engine in its own department. For example, the engine-cylinder barrels are rough-turned and finish-turned; fins on the barrel rough- and finish-turned; and the threads on the bottom of the barrel are ground, all in one section of the shop. The grinding depart-

ment is the only strictly operations department. It is used principally for parts on which grinding is the primary operation.

TABLE 2.—EQUIPMENT IN THE PRODUCTION LINE

No.	Machine	Operation
1	Cincinnati No. 2 miller	Mill locating pad
2*	112-in. Newton rotary mill	Mill top and bottom of block
3	Barnes drill	Drill and ream two $\frac{3}{4}$-in. locating stud holes
4*	Barnes single-end horizontal-boring machine	Rough-bore main- and camshaft bearings
5*	Barnes double-end horizontal-boring machine	Semifinish-bore main- and camshaft bearings; finish-bore starter and generator saddle
6*	8-spindle Moline boring machine	Rough-bore cylinders
7*	Newton duplex planetary	Mill ends to length and mill fan pad
8*	DeVlieg Supermil	Mill boss flanges on both sides
9	Ingersoll mill	Straddle-mill bearings to length
10	2-way Colburn drill	Face cam bearings
11	Natco 2-way horizontal drill	Drill and ream breather hole and fuel-pump hole
12*	Kempsmith No. 2 Maximiller	Finish-mill water pump pad
13	Baush 3-way drill, bridge type	Drill 60 holes in top and both ends
14	36-in. Moline 16-spindle drill	Drill sixteen $\frac{9}{16}$-in. tappet holes
15*	Barnes single-end horizontal-bearing machine	Finish bore main and camshaft bearings
16	36-in. Moline 16-spindle reamer	Semifinish ream 16 tappet guide holes
17	Hammond radial	Chamfer guide holes
18	Baush 3-way drill	Drill 122 holes in bottom and sides
19	Barnes vertical 1-spindle automatic reamer	Finish-ream valve-tappet guide holes
20	36-in. Moline 8-spindle drill	Chamfer bottom of cylinder bores
21*	Moline cylinder borer	Finish-bore cylinders
22	20-in. Barnes drill	Chamfer top of cylinders
23	Davis & Thompson 6-spindle drilling and boring machine	Drill, spot-face, bore, and ream distributor hole
24	5 Baker No. 217 drilling machines	Finish-ream cylinder bores, one at a time
25	Millholland unit drill heads (3)	Drill oil, water, and lockscrew holes
26	Baush 3-way tapping unit, bridge type	Tap holes in bottom and sides
27	Millholland unit drill heads (4)	Drill 16 holes and tap 2
28	Baush 3-way tapping unit	Tap 43 holes in ends and top
29	Barnes lapping machine	Lap cylinder bores
30	Washing machine	Wash complete casting
		Inspect

* Tooled with tungsten carbide.

A study of the floor plan, Fig. 15, and the designation of the machines by the symbols shown will give a good idea of the machine and other equipment, as well as the arrangement.

The Vultee Airplane Machine Shop.—The machine shop is a small part of the plant in an airplane factory, as can be seen in

the Vultee Airplane shop in Fig. 16. It occupies but 4000 sq. ft. of the total floor area in the airplane factory. Yet it is extremely important to have a machine shop and to have the

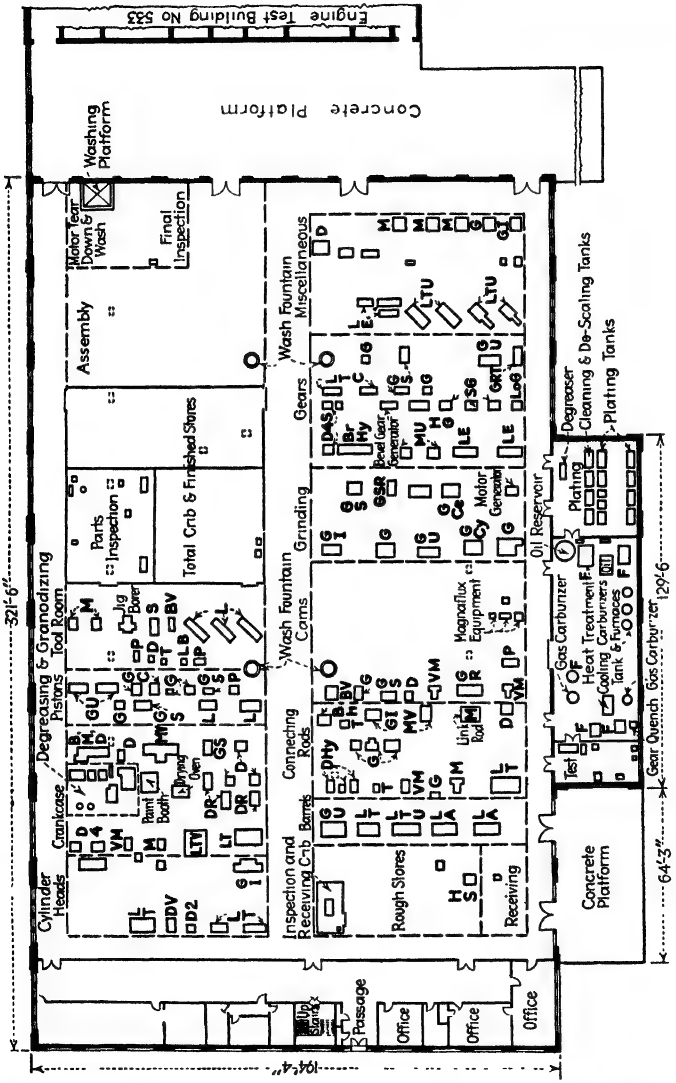

FIG. 15.—Small airplane-engine plant.

tools arranged conveniently for the work. There are eight standard milling machines and two bench millers, a fair-sized lathe department, and numerous drill presses and benches in

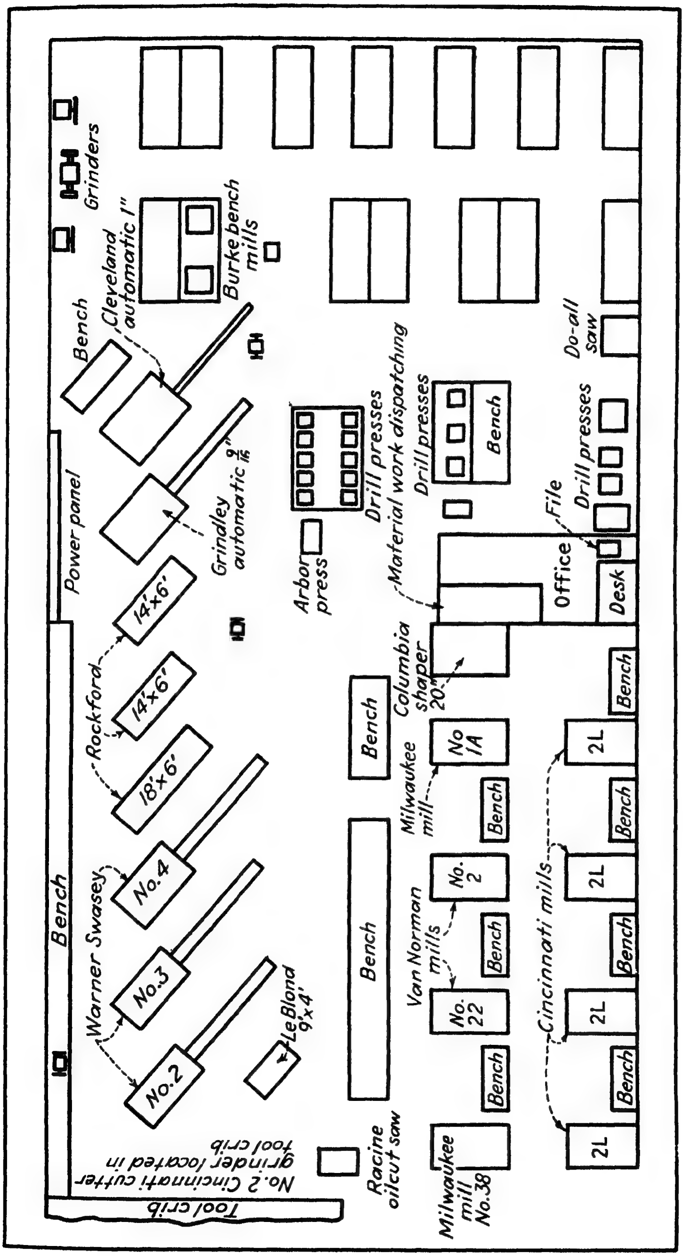

FIG. 16.—Airplane-plant machine shop

convenient locations. The tool crib is in the upper left-hand corner, and a small office is provided for the foreman and his clerk. Numerous jigs and fixtures reduce costs and secure interchangeable parts. Much of the drilling must be accurate to receive mating parts, and 0.002 in. is a common tolerance.

Saving Space by Rerouting Work

The Geometric Tool Co. doubled its output of chasers for its die heads using only 60 per cent of its former floor space by rerouting the flow of work, as shown by the accompanying diagrams.

A careful study of the floor plans shown in Figs. 17 and 18 will reveal the saving in distance traveled and the freeing of large spaces for other work. These are marked Vacant on the floor plan in Fig. 18.

It will be noted that the space occupied by the machine department has been practically cut in half in the new arrangement. This is made possible by replacing the old machine tools with newer ones with greater capacity, as much as three times the production being secured in some cases. This reduction of machine-shop space permitted the grinding department to be moved from the room separated by the tunnel to the space abandoned by the machine shop, thereby greatly reducing the travel of the work in process.

This is an excellent example of the advantages of better machine equipment and the savings it makes possible in space and travel of work.

Saving Work Travel.—An excellent example of saving a large amount of work travel is that shown by C. G. Johnson, of the time-study department of the Westinghouse Electric & Mfg. Co., in the motor-frame machining group Fig. 19. His analysis of the problem follows and will be helpful in studying other cases of shop layout and production movement. In *Factory, Management and Maintenance* he says:

Plant layout, though out of the realm of simultaneous two-handed operations, participates in the dividend declared by motion analysis applications. Up to this time little has been written upon this phase of motion economy, but this fact does not lessen the enormous savings possible.

When making an analysis of the layout in the department to find out if costs may be reduced by changing this layout, the following questions are asked: Are conditions—lighting, ventilation, heating, and the like—all that they should be? Is the equipment the best for the job? Is the supply system all right? Could mechanical handling equipment be

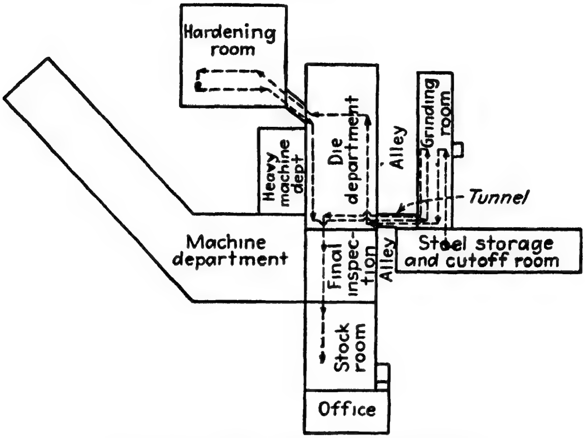

FIG. 17.—Plant before rearrangement.

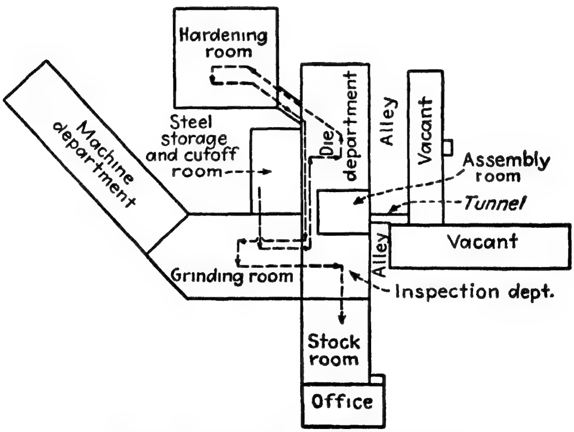

FIG. 18.—Space saved by new layout.

installed to do away with manual handling? While the machine is making a cut, is there idle time which could be utilized productively? Do the operations follow in logical sequence?

It is difficult to say just how much conditions will affect the time it takes to do a job—in fact, the effect will probably be greater on one job

than another. However, it is known that poor conditions have a detrimental effect on output, whereas good conditions tend to increase production and build up good-will. Factors contributing to the comfort of the workmen will always repay the cost of installation.

The right equipment for each job is one requisite. Various machine tools have been developed to do various types of work. Although a milling machine and a profiler can each do some operations in common, each one can do certain jobs more quickly than the other. Therefore, to get maximum and least costly production, the machine-tool equipment must be right.

The supply system is a problem which must be given considerable thought. Whether parts are brought from a storeroom on a conveyor or from the receiving department on a skid truck, they must be placed close to the machine where they are to be used and in a position most convenient for handling.

In addition to getting the raw product to the machining line, it must be handled from one operation to another. To do this manually is unwise from all viewpoints. At the present time mechanical handling equipment in the form of belt, roller, or chain conveyors, monorails, gravity chutes, etc., can be provided to handle practically any job.

It has long been accepted practice for one operator to run a battery of automatic machines. All automatics are usually so placed that the greatest number can be run advantageously. The operator's duties are to keep his machines stocked and inspect a sufficient number of completed pieces to make sure that they are according to specifications. Thus the number of machines that any one man can operate is determined by the machining time and the accuracy required. An analysis of machine-tool layouts in our plant has shown numerous cases where these same principles can be applied to nonautomatic machines. Very few jobs, where the machining time is of long duration, require the undivided attention of an operator. By incorporating these principles, always used in placing automatic machines, in the placing of nonautomatic machines, cutting time may be utilized for productive work.

Last considered, but by no means of least importance, is the sequence of operations. This brings to mind the two general types of layouts—first, the section where miscellaneous work is done; second, the one where there is straight-line production. In the former type, the usual sequence of machines is lathes, profilers, milling machines, and drill presses. There will always be numerous variations in this line-up. For straight-line production, machines must be placed in such order that the necessary operations can be most easily performed without backtracking. This is clearly illustrated in one of the examples which follow. Parts going back and forth needlessly cause much confusion in the plant and greatly slow up production processes.

The need for motion analysis in plant layout is apparent. Two illustrations of possible accomplishments, developed by our layout department in conjunction with the shop supervisory force, are now presented. They are representative straight-line production jobs.

The old and new layouts of a motor-frame machining group are shown in Fig. 19. In the past, ten operators performed a total of ten operations on each frame. The part was moved back and forth from one operation to the next by a materials handler or by the machinists them-

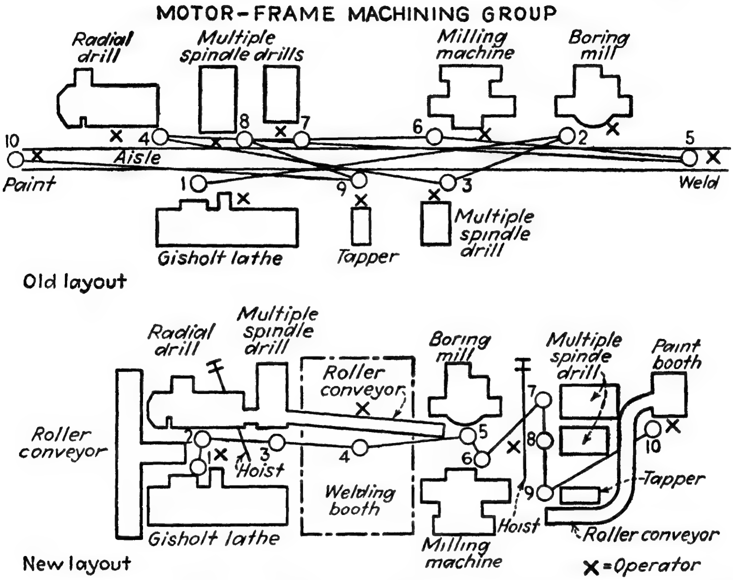

FIG. 19.—Compare the old layout on each side of the aisle with the new, and follow the movement of the work by numbers. The change reduced the number of men from 10 to 4.

selves. The machines were not placed so the operations could follow in proper sequence, consequently there was considerable back-tracking.

After study and analysis the new layout was made. Here the machines have been regrouped to permit coupling and allow the frame to go in logical sequence from one operation to another. Conveyors and electric hoists were installed to eliminate all manual handling. Machine waiting time has been eliminated and the operators are able to produce two and one-half times as much as they could before.

Layout for a Job Welding Shop

The layout and equipment shown in Fig. 20 received the first award in its class in the 1938 contest of the J. F. Lincoln Welding

Foundation. The authors were Howard McCord and Ferd H. Drewes of the W. G. Jarrell Machine Co.

The extent and arrangement of equipment in a commercial or job welding shop must be consistent with budget limitations. Existing buildings and facilities often must be adapted to the requirements of the shop and, at the start, it is perfectly feasible to install only one piece

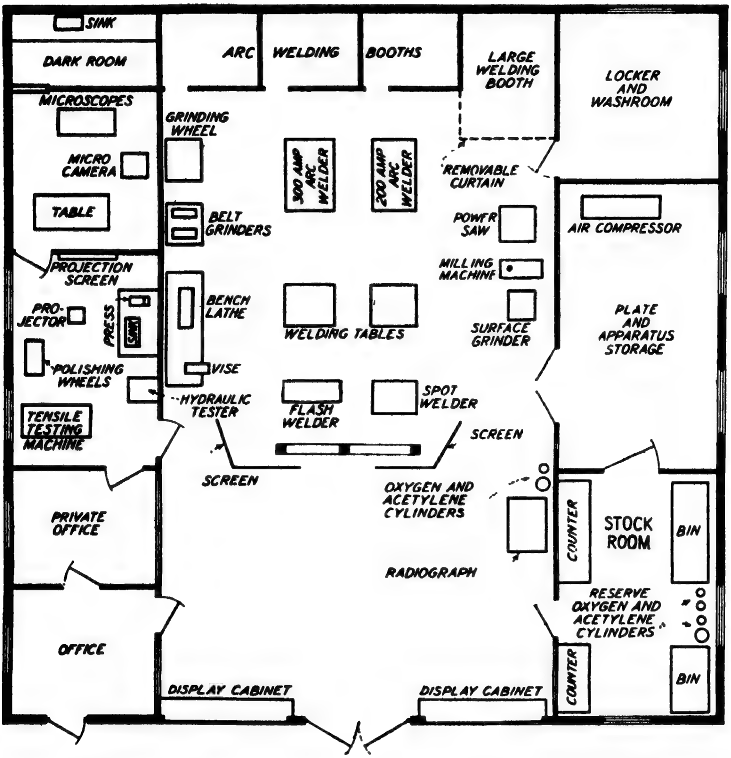

FIG. 20.—This includes several kinds of welding apparatus and some machine tools.

of equipment in each of the departments and still have a well balanced shop. Material handling facilities must be adequate if profits are to be realized; material handling methods of 1920 cannot compete in the 1938 market.

The model arc-welding shop for which a layout is shown has been planned for profitable operation on a fairly wide range of electric arc and oxyacetylene welding jobs. The equipment for testing welds provides facilities for a constant check on weld qualities and the efficiency of the individual welders.

In the model shop shown, the 300-amp. arc welder is a gasoline-engine driven unit mounted on a trailer so that it can be taken out of the shop for on-the-job welding. The flash and spot welders should be selected for wide adaptability, unless contracts for individual jobs justify the purchase of special-purpose units. These units need not be installed at the start, but once set up will find many uses.

Experience has shown that the following sizes of plate stock should be carried in the storeroom: $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{4}$, 4, $4\frac{1}{2}$, 5, $5\frac{1}{2}$, 6, $6\frac{1}{2}$, and $8\frac{1}{2}$ in. Round bars should be available in the following diameters: $\frac{1}{2}$, $\frac{3}{4}$, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, 4, 6, 9, 12, 14, and 16 in. The stock also should include standard channels, I-beams and angles, as well as the necessary supply of different sizes and grades of welding rods, electrode holders, goggles, gauntlets, shields, fireproof curtains, torches, and hose.

In organizing a commercial welding shop one of the essentials is the selection and training of the welders. The applicant should be familiar with the operation and adjustment of the equipment in use in the shop and must be thoroughly grounded in the fundamentals of arc welding. Demonstrations of ability should be demanded of each applicant. Manufacturers of welding equipment and electrodes furnish the purchaser with literature giving recommended applications and producers that will guide the proprietor.

Each job should be checked carefully and the data compiled and made available for consultation once a week for the purpose of noting the progress of the new employee in such matters as welding speed and pounds of electrodes used per foot of weld. Discussions at a weekly meeting, with employer and employee alike offering suggestions, will result in each having a clearer understanding of each other's problems.

REARRANGING OLD PLANTS

Sullivan Machinery Co.—The buildings of this company at Claremont, N.H., are not new but have an unusual number of large windows for an old plant. Built on the edge of a mountain stream, the buildings vary from one to five stories with the slope of the ground. This makes the handling of work from floor to floor a real problem. As a result, the plant is departmentalized by products, keeping each product on one floor if advisable, but confining it to two floors in the worst cases.

The plans, Figs. 21 and 22, show the way in which work in the hoist department is carried out, including, of course, the machine layout. Hoists are made in lots of from 6 to 50, but parts are made in lots of from 6 to 300. About 4000 pieces are involved in

making these hoists, and there are 80 machine tools in the department.

About 50 per cent of the floor space is occupied by machine tools which have been grouped to eliminate trucking service so far as possible. Bar machines have been lined up along the windows to give the best possible lighting and to keep feed tubes out of the way. A Jones and Lamson chucking machine is at the end of the line for second-operation work, and a 3A Warner and Swasey is used for rope drums located near by. These

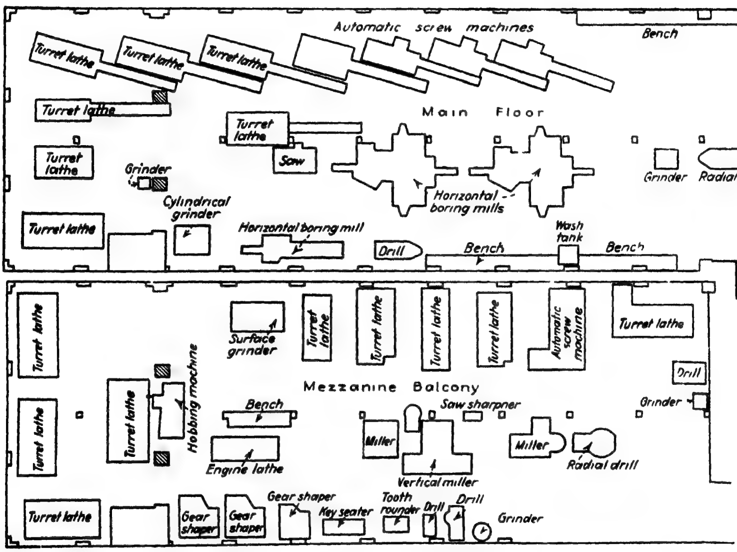

FIG. 21.– Machine layout of main floor and mezzanine.

machines are under the mezzanine balcony, which occupies one end of the main shop.

On the balcony itself are the chucking machines and allied equipment for producing gears, gear hubs, and similar units. Four Potter and Johnston chucking machines are grouped at the end of the balcony to be run by one operator who sets his own tools and grinds the drills and single-point tools he uses. The largest gear hub used is too big for the Potter and Johnstons and is finished complete on an Acme. Cut time is long enough to allow the Acme operator to do a drilling job on an adjacent Barnes drill.

Gears turned and faced on the Potter and Johnstons go direct to the gear cutters and thence to stores. Drums on which internal teeth are to be cut, go to a nearby Blanchard to have a seat ground before they reach the Fellows machines.

Erection is done in the southeast end of the department where crane service is available. Here the larger machines, planers,

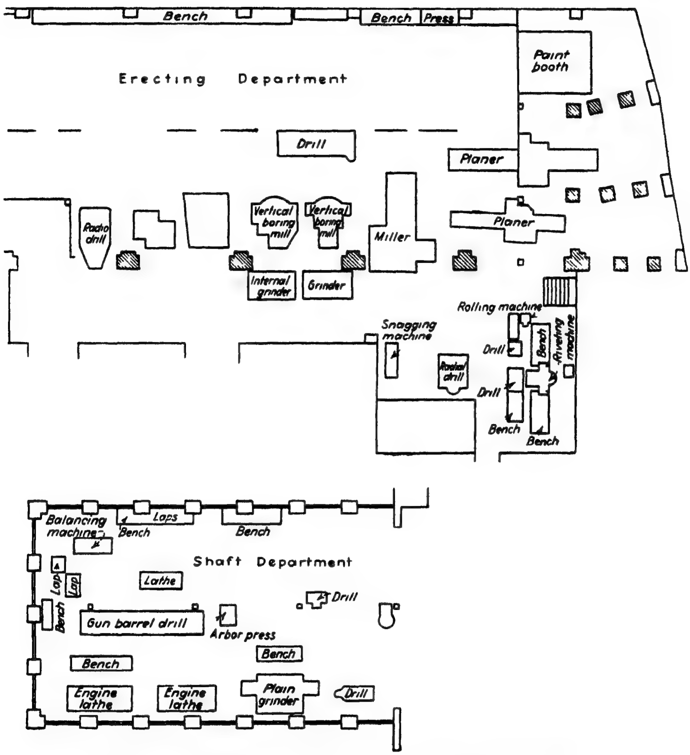

FIG. 22.—Erecting floor and the shaft department.

vertical boring mills, horizontal boring machines, and radial drills are located. Back of them, on the best foundation in the department, are the grinders to which parts come directly from the near-by heat-treating department. Near the grinders is a small group of machines and benches for assembling brake bands. Here the flat steel is drilled and rolled into band form, and brackets are riveted on.

Hoists are assembled on horses and are then trucked into the paint-spray booth. From the booth, they are elevated to the upper floor and trucked to finished stores. The parts are carried in assembly racks, each rack holding parts for six hoists.

Shafts are turned and recentered on two engine lathes and drilled on a gun-barrel drill in a smaller department back of the main shop. After grinding they go up to the balcony to have keyways milled. This arrangement involves extra transportation, but as the choice was to put the milling machine in one of the two departments, it was decided to put it in the balcony because there was more milling work in the gear department than in the shaft department.

The illustrations, Figs. 21 and 22, show the floor layout of the four departments in which this work is completed.

Changing Layout to Reduce Movement of Materials.—Figures 23 and 24 show how the plant of the Norton Company, Worcester, Mass., was rearranged to save time and labor in handling material and to speed up production. As in most cases, the original plant was a growth from small beginnings, each increase taking the form of a new building, or "mill," as some call it. A study of the old arrangement, especially of the flow chart, or diagram, of the movement of material, shows the way in which the material moved back and forth, crossing itself at various points. It would have been easier to start with a new plant, but this is seldom possible, and the way in which the routing was improved reflects credit on the planning department.

Formerly the material was transported by industrial truck from one building to another through the connecting cross aisle at one end. An industrial track for heavy work was put in at the other end, but the old passageway was kept for lighter materials. This made it advisable to rearrange some of the machinery in order to machine the heavy parts near their point of entrance. The new arrangement has greatly simplified the flow of material and eliminated the crossing of heavy and light parts.

An interesting feature of the change is an increase in plant capacity of about 25 per cent without adding to the floor space. In fact, the new arrangement leaves several bays free for additional machines when needed. This possible increase amounts to another 20 per cent. New machine equipment made some of this increased capacity possible.

Tool cribs were also decentralized. This decreased the setup time in the machining departments. Nine tool cribs now supply the six mills, or buildings, their location being determined with a view to accessibility from all the departments.

The interior painting of the shop is also a factor in production for it tends to a clearer vision. The walls are painted with aluminum for five feet from the floor. Above this line the walls are painted in mill white, which is also on the ceilings. In the heat-treating department all equipment is in aluminum. The machine tools are the standard blue-gray. The whole effect is pleasing, and the general air of light and cleanliness is increased by ample aisle space.

Rearrangement of a Plating Plant.—The plating department of the International Business Machines Corporation had reached the limit of its capacity with its original layout, and greater output was necessary. Therefore, the layout and the methods used were carefully studied. On casual examination there was nothing wrong with the original layout, shown in Fig. 25. But to nickel- or cadmium-plate any part, all work was being wired and unwired, and very few racks were being used.

In loading and unloading still tanks of cadmium and nickel, the very arrangement of the plating tanks, and particularly of those in the cleaning line, prevented carrying out operations on anywhere near a straight-line production basis.

Because under no condition could additional floor space be obtained, it was decided to replace all but two of the still-nickel tanks with a semi-automatic nickel-plating unit, and all but one of the still-cadmium tanks with a semi-automatic cadmium-plating unit. An additional chromium-plating tank was put in to take care of the increased requirements for chromium-plated parts, and suitable racks were obtained so that as many parts as possible could be racked instead of being wired on copper wire. To guarantee sufficient current for the additional chromium tank, as well as to ensure satisfactory operation of the semi-automatics, two 2500-amp. generator sets were installed in addition to the 5000-amp. generator already in use.

The final result of the rearrangement of the cleaning line and the installation of the new equipment referred to in the following paragraphs, together with the adoption of racks in place of individual wiring of parts, was an increase of approximately 40

per cent in production capacity and an approximate labor saving of 14 per cent.

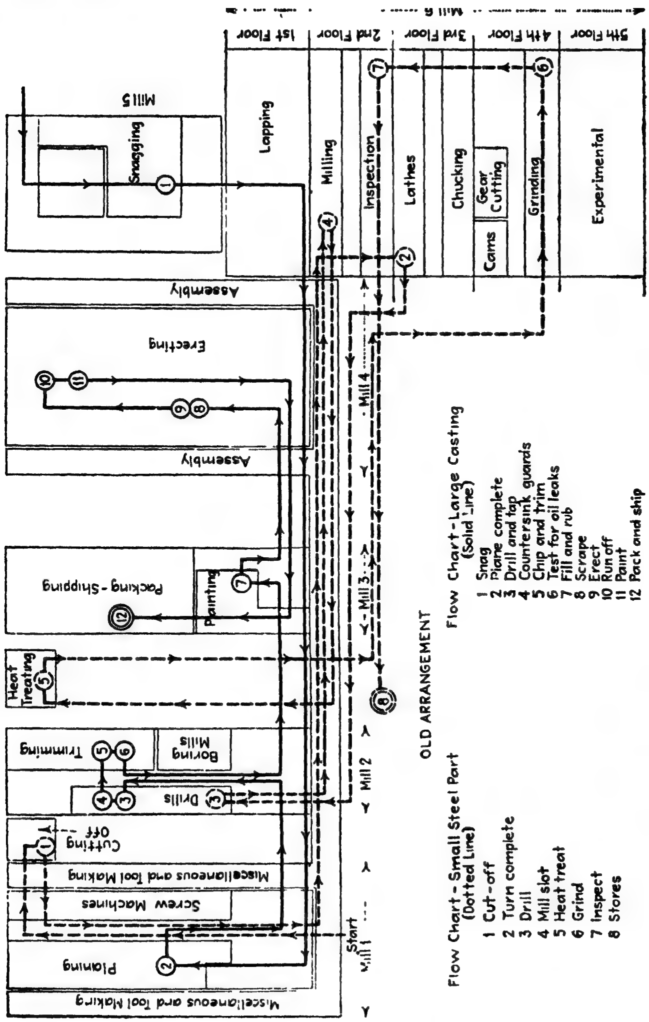

FIG. 23.—Note the long line of work travel in this layout.

Reference to the floor plan in Fig. 25 will show how the department was rearranged and indicate the location of the new units. The new layout included two semi-automatic plating machines, one for nickel, the other for cadmium. These are shown in Fig. 26. The nickel-plating machine is a variable-speed

machine, 22 × 4 × 2 ft. The tank is constructed of $\frac{1}{4}$-in. steel plate double-welded inside and outside, and is lined on all inside

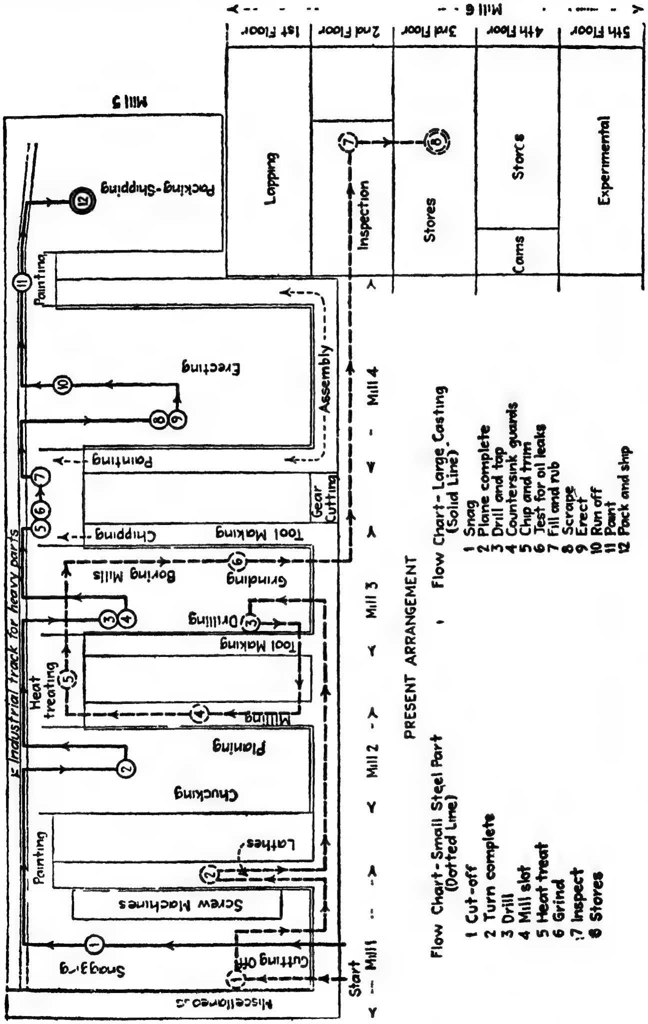

FIG. 24.—Rearrangement shortens the work travel.

surfaces and over the reinforcing angle with $\frac{3}{16}$-in. rubber lining suitable for nickel plating.

The conveyor in this tank is driven by a Varidrive motor, 220-volt, 60-cycle, 3-phase, giving a variable-speed regulation from 20 to 80 min. per revolution. The conveyor chain has

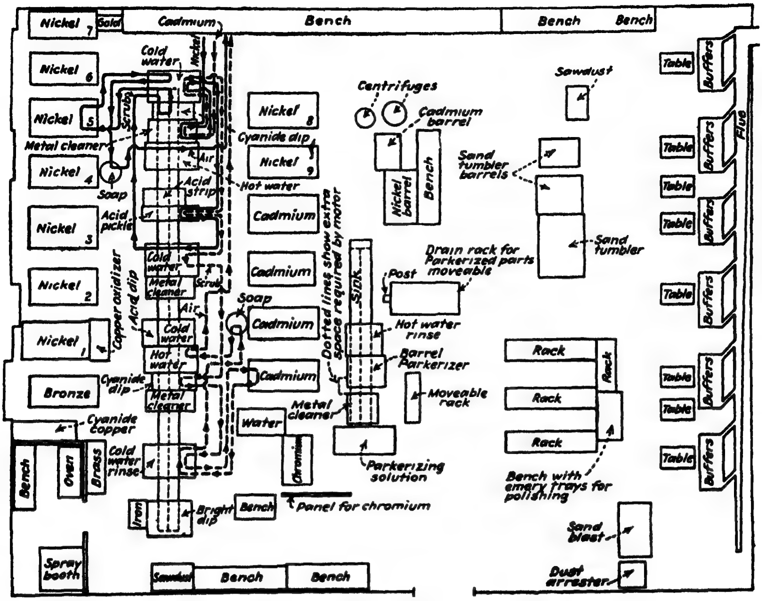

Fig. 25.—Original plating room layout.

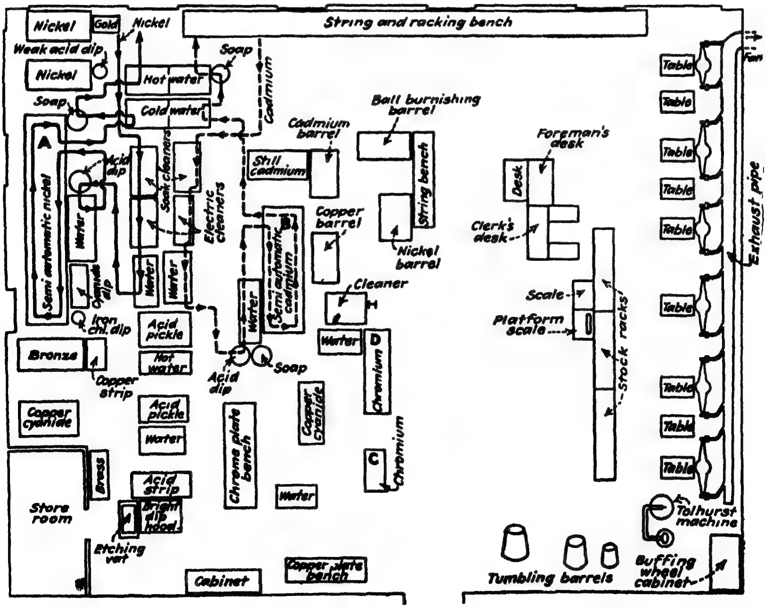

Fig. 26.—This rearrangement saved time.

cathode-hook attachments cast on 3-in. centers with collector-contact cathode hooks mounted on 6-in. centers, the hooks being swiveled and compensating for all loads to guarantee perfect electrical contact. This unit is capable of handling either single-hook racks or racks having two cathode hooks. The anode and cathode conductors will carry 2000 amp. of current without heating and loss of efficiency. Equipment includes a chemical-lead steam coil 1½ in. outside diameter, approximately 100 ft. long, with two insulated steam joints; a single-acting recording temperature controller with a range of 50 to 150 deg. F.; and a 2000-amp. rheostat with a 3-volt drop, equipped with voltmeter and ammeter having 54-step regulation.

Semi-automatic Plating Machines.—In practice, the advantages of the semi-automatic nickel-plating tank over still tanks are: (1) more uniform thickness of plate; (2) denser and more ductile plate with less tendency to peel and crack; (3) reduction in plating time; (4) increase in hourly production capacity.

For cadmium plating, a variable-speed semi-automatic machine, 12 × 4 × 3½ ft., was installed. It is indicated at *B* in Fig. 26. This tank is of the same construction as the nickel tank just described, and its conveyor is driven by a corresponding motor, the only difference being that speed regulation is from 4 to 20 min. per revolution. The conveyor chain is of the same type as that used in the nickel unit.

The advantages of the semi-automatic cadmium unit over still tanks are: (1) uniform plate of approximately 0.0002 in.; (2) increase in handling production capacity.

At *C* in Fig. 26 is a chromium-plating unit 4 × 2 × 3 ft., also made from ¼-in. plate double-welded at all joints. It is equipped with angles, adjustable cleat holders, three pairs of cleats to accept two anode and one cathode rod made of 2- × ½-in. copper. The tank is lined with 8-lb., 6 per cent antimony lead and equipped with an exhaust casing made from 14 gage steel of all-welded construction. In one end of the tank is a lead coil made of ¾-in., 3½-lb., 6 per cent antimony lead, equipped with solution-level protecting sleeves made of ¾-in. iron nipples sweated on and ¾ × ¾ in. insulating steam joints. A Duplex tempertaure-recorder controller has a range of 50 to 150 deg. F.

The other chromium-plating tank, *D* in Fig. 26, is 8 × 2½ × 3½ ft. and is lined with 10-lb., 6 per cent antimony lead. There are

an exhaust hood and a lead steam coil on the side of the tank which is equipped with four 1½-in. solid-copper anode and cathode bars, lengthwise of the tank, and seven 1¼-in. solid-copper anode bars and six 1¼-in. solid copper cathode bars crosswise of the tank with connections for the main busbar. An exhaust fan draws air from the hood.

Changes in Plant Layout for Varying Production.—Better production control, improved supervision, reduced material handling, and lower costs are among the rewards of good equipment arrangement, as in the White Motor Company. But many variables must be weighed to achieve the most advantageous layout.

In the arrangement of plant equipment there are, generally speaking, two methods open to the manufacturer:

1. Segregation, or grouping, of machinery according to class of work.
2. The assignment to each group of the equipment required for the complete manufacture of an assembled unit arranged scientifically in sequence of operation.

Which of these two arrangements is the more economical depends upon the type and variety of the products to be manufactured. In some manufacturing plants, the former method may lend itself better than the latter, and in others, the contrary is true. Each method has its advantages and disadvantages which must be remembered in deciding the method to be employed.

Grouping by Machines.—For the first method, which groups the machines according to type, the advantages may be summarized as follows:

1. Higher degree of flexibility in manufacturing capacity.
2. Maximum machine activity.
3. Minimum of duplication of equipment.

The disadvantages of this grouping are:

1. Increased handling of work.
2. Necessity for process inspection between departments or groups.
3. Setting up a system of controlling production and coordinating the efforts of each department or group.

Grouping by Work or Line Production.—For the second scheme of arrangements which groups the equipment required for the

complete manufacture of a product within one department, the advantages may be summarized as follows:

1. Ease of production and schedule control.

2. Elimination of departmental difficulties by having the entire manufacturing process on each product under centralized supervision.

3. High degree of efficiency by specializing the efforts of each operator.

This also has disadvantages, such as:

1. Higher investment in plant facilities.

2. Minimum machine activity, particularly during dull times.

3. Maximum duplication of equipment.

However, the latter method is particularly adaptable to work that can be divided into many elements with each element being performed by a separate workman. Under this system in production shops, an ordinary laborer can be taught in a few hours to fill any missing link in the long chain of production. The individual workman does one part of a job over and over again. Logically, he does it as well as, if not better than, a man who has to spread himself over many jobs.

At White Motor Company, because of the great variety of parts that must be manufactured and varying production schedules, both methods naturally are practiced. There are, of course, some departures therefrom in the case of products manufactured in small quantities and where, in our judgment, a different arrangement is more economical.

In modern manufacturing, overhead costs are important, and if there is one item above another that increases overhead, it is the improper routing of the work through the plant. The manner in which the work is routed through the shop is influenced by the arrangement of the equipment within the shop. The modern plan is to have the work flow through the plant in as nearly a straight line as possible, for every backtrack means added expense.

Increased Efficiency.—It was decided to make the axle department 100 per cent self-contained. To do this, it was necessary to move the axle-housing machining department. This department had been expanding for several years, and it had become necessary to add new machine-tool equipment. This equipment was added in a general way depending upon the space available,

and as a result, the operations were no longer in proper sequence and considerable trucking was necessary. After a survey of the sequence of operations, a strictly progressive line was made with about 6 to 8 ft. between machines for banking of stock between operations.

With this new arrangement of equipment and each man working individually as before, the efficiency of operation rose on an average of 12 per cent. The objection to this line was that the shop layout did not allow sufficient space for stock. To overcome this objection, it was decided to group the line and have each operator share equally from the housing production as a whole. With this cooperative arrangement, the efficiency of operation per man was further increased more than 20 per cent with a request to place machines closer together, which was done. This illustrates how production may be increased with available facilities by rearrangement of machines without investment in new machine tools or additional tooling.

Many reasons undoubtedly could be advanced by the executives of some shops why they do not discard their old machine tools and replace them with machines having higher productivity and why they are content with improvised tooling methods for any particular job. But there is no good reason under any circumstances why the machinery should not be arranged to obtain the highest possible operating efficiency, no matter what the nature or condition of the machine tools or tooling employed. The proper arrangement of the equipment in any plant is the least expensive way of increasing production, and the effort involved will be paid for many times over in increased efficiency of operation.

In keeping up with changes in design of the product or changes in manufacturing methods, the rearrangement of equipment in a large plant having some 2500 machine tools is almost an everyday function. To provide a better means of manufacturing and not relocate the machines is only doing half the job, and in some cases, the benefits anticipated by the improvement in manufacturing method may be lost by improper location of the equipment involved.

The location of departments also plays an important part in reducing manufacturing costs. An important thing to remember is that in no phase of manufacturing are there greater possibilities

for substantial savings than in the process of moving materials from machine to machine or from one department to another.

These problems can often be worked out by means of some kind of a conveyor, either gravity or power. This, of course, is costly from the standpoint of initial investment, and because of uncertainties, one may be just as reluctant to install such a system as he would be to replace his machine tools with those capable of higher productivity. The ideal situation, however, when a plant has a number of different departments is that they be located and coordinated so as to reduce the problem of material handling to a minimum.

White Motor Company had departments so arranged as to reduce the movement of raw and finished materials to a minimum. The departments were also practically self-contained according to major units, such as engine division, axle division, and transmission division. Under the system, each department performed practically all classes of work except heat-treating and other special operations, such as plating and polishing. The latter departments were centrally located and concentrated. The one other special department was the screw-machine department which made all screw production and kindred work for the entire organization.

There was also a grinding department which did nearly all the grinding for the entire organization. This setup prevented every department from performing all the successive operations on any part requiring grinding which meant considerable trucking of parts. The grinding department was finally broken up, and the machinery distributed to other departments according to their particular needs.

Progressive Machining.—Despite the great variety of models manufactured and the varying production schedules, machine lines were arranged for progressive straight-line machining according to sequence of operation with carefully worked out material-handling facilities. Lines for progressive machining include such essential parts as cylinder blocks, crankcases, crankshafts, connecting rods, pistons, and axle housings.

In order not to be overburdened with special-purpose machine tools and tooling for those parts, adaptability rather than special use because the watchword; but at the same time, the equipment was kept up with latest methods consistent with

production requirements. In the selection of machine tools the company tries to decide on the correct place for a standard type of machine as compared with a special- or single-purpose machine. Standard machines adapt themselves better to lowered production schedules.

Progressive machine lines are used where possible. They make, for example, six sizes of standard pistons ranging from $3\frac{1}{2}$ to $4\frac{5}{8}$ in. in diameter. These are all made on one machine line of 10 machines, all except one being standard. Three distinct lines for machining cylinders come together at the washing machine, then continue on one conveyor line to subassembly and final honing and back through the same washing machine.

Flexibility.—Flexibility is particularly necessary in erecting chassis, especially as there are 30 models ranging from 8500 to 32,000 lb. These are assembled on one conveyor line. The power chain moves at 3 ft. per minute. Ten men work on this section of the line, and the standard earning is 60 cents per hour for this work. This means that the group must earn 10 cents per minute or $3\frac{1}{3}$ cents for every foot of chain travel. With this as a basis, any chassis can be run over the line without confusion by spacing the chassis the proper distance apart to keep the men in their respective zones.

Suppose, for example, a certain chassis cost $1 to assemble. This type of chassis should be spaced with 30 ft. between the front of one and the front of the next. For a chassis costing $2 they should be spaced 60 ft. apart. The cost of the job divided by the money per foot gives the proper spacing of the chassis on the line.

Lowered production often makes it advisable to relocate some machines so that operations can be combined and handled by one operator. A little study will show where this can be applied successfully.

GROUP DRIVES

There are many arguments for and against group drive, but production, layout of machinery, and many other factors should be considered in determining which method of drive to use. Furthermore, the efficient method used today may be inefficient tomorrow because of some change in one of the many factors deciding the type of drive.

During normal times, all motors were fully loaded, which resulted in good power factor and consequent reduction of power costs. However, during a low-production period a line shaft driven by a 50-hp. motor was driving only a few machines. Consequently, the motor was underloaded, the power factor dropped, and power costs increased.

Proper Line-shaft Grouping Reduces Cost.—To overcome this condition some reengineering was required which, when completed, justified itself by a reduction in power costs. This was accomplished in the regular production departments by cutting off the motor driving one line shaft and driving the shaft by belting to the next line shaft. The same result was accomplished in other cases by substituting a smaller motor for the lightly loaded large motor. In the noncurrent department where the machines are for the most part arranged according to type, it was conceived that if one of each kind or type of machine was grouped under one line shaft, they could take care of all the production requirements without running the whole department.

This was done, and the move undoubtedly paid for itself many times over. This group of machines also came in handy when the department was called on, to perform some rush job at times other than during the regular working hours.

Power Is Saved.—Another factor to be considered in regrouping machines and changing drives is the saving in power consumption. A line shaft driving only three machines out of a large group may require, say, 25 hp. divided into 15 hp. for the machines and 10 hp. for line-shaft losses.

A regrouping would perhaps require a 20-hp. motor, the same 15 hp. being used for the machines plus only 5 hp. for line-shaft loss. Fitting a motor to the job results in an additional power saving since in the first case the motor efficiency at half load would be approximately 67 per cent, and in the second case it would be approximately 90 per cent. Calculation would show in the first case a $37\frac{1}{2}$-hp. input is required and in the second case a 22-hp. input or a total saving of $15\frac{1}{2}$ hp.

In any plant where machines are being constantly rearranged to maintain maximum operating efficiency under any circumstances, the efficiency of the transmission equipment, if not closely watched, may become greatly impaired. Inadvertently, this factor may be overlooked during good times unless it gets

out of balance so badly that it would be apparent to a casual observer.

Arrangement of Machine Tools.—Economical and efficient arrangement of machine tools depends largely on the nature of the work and also, to some extent, on the space available. In mass production the line method is necessary, so that the work flows in as straight a line as possible through the different operations to the assembly line. In a job or contract shop, and this also applies to plants in which the quantity is never large, it is usually best to arrange machines by function, with lathes, milling machines, planers, and other machines each in their own group. The case of the Generator Department of the Westinghouse Electric and Manufacturing Company, as told by H. D. Ege, shows the saving resulting from combining the machine equipment of several departments. These departments had been originally divided according to the size of the apparatus built. Combining the machine equipment eliminated an excess capacity of about 30 per cent and also eliminated an overhead expense of about $35,000 per year. Some of the results of the study made previous to the change are shown in Table 3.

Table 3.—Partial Machine-tool Summary

Name	Present equipment	Number required if grouped according to function	Number that can be eliminated
Vertical boring mills	53	44	9
Planers	16	16	
Radial drills	34	30	4
Sensitive drills	39	22	17
Turret lathes	22	11	11
Engine lathes	45	36	9
Horizontal boring mills	16	15	1
Milling machines	32	17	15
Profilers	9	2	7
Grinders	14	9	5
Shapers	4	2	2
Slotters	9	4	5
Keyseaters	8	4	4
Hydraulic presses	11	6	5
Total	312	218	94

A CONTRACT SHOP PLANNED FOR THE PURPOSE

Few contract shops are planned for their particular purpose. They are more likely to be the outgrowth of a small jobbing shop, perhaps in some loft building, if they are located in a city, and not well arranged for the work they are to do. The shop shown in Fig. 27 was built for the purpose when the firm outgrew the small shop where it started.

The layout of jobbing-shop equipment, office, and laboratories is frequently handicapped by a building that was originally intended for entirely different purposes. No such handicap exists in the building illustrated, for it was designed to suit a planned layout.

The building proper is approximately 300 × 55 ft. The sizes of the other details can be readily estimated from these dimensions. The supporting columns are along the center of the shop.

As in most shops in which a variety of work is handled, the machines are for the most part grouped into departments according to the operations performed. Lathes and milling machines occupy one end of the shop. Planers and shapers are grouped together along the outside wall with horizontal boring machines near by.

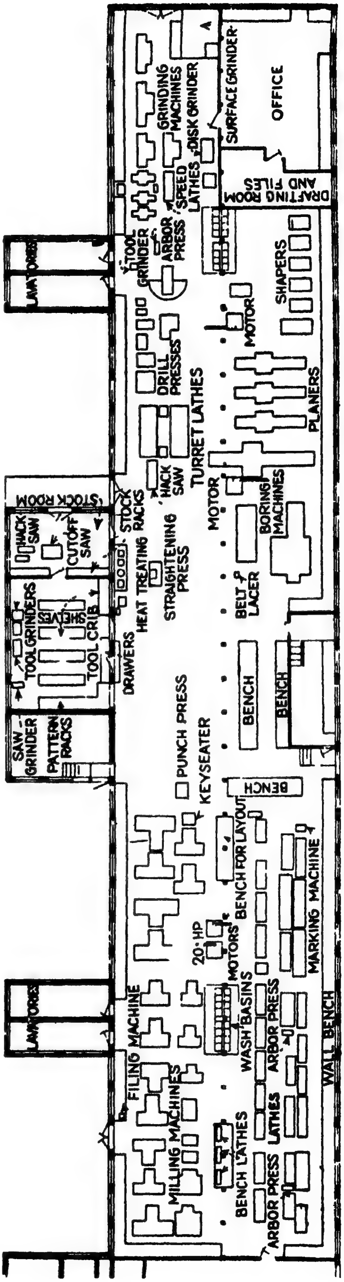

FIG. 27.—A job shop that was planned to handle a variety of work.

Drill presses, both vertical and radial, and turret lathes are placed opposite the planers. The grinding machines are placed in the corner near the office. It will be noted that arbor presses are located at various points as needed. A speed lathe is placed near the grinders. Other miscellaneous machinery, such as marking machines, filing machines, and tool grinders, are placed in convenient locations. Bench space has been provided both along the walls and wherever needed through the center of the shop. The layout benches are placed near the machines requiring that sort of work.

Power in most cases is obtained from electric motors which operate sections of the shop by the group-drive system. Larger machines have individual motors. Since the original layout, the tendency in this plant has been to equip nearly all machines with individual motors. This is considered particularly desirable in a contract shop because of the wide variety of work that has to be handled. Individual motor drive is also more satisfactory for overtime work when only one machine or operation is required.

This layout does not show facilities provided for handling material. Overhead cranes are provided for the machines that handle heavy work, such as the planers and boring machines. Hoists were also provided at various points to facilitate the handling of work and heavy machine parts. This saves time and conserves the energy of the men, adding to their comfort and leaving them in better condition for doing accurate work.

One of the principal advantages of having a shop built according to original specifications is that any extraneous departments or rooms may be placed outside the regular working areas. The tool crib and the raw stockroom and the lavatories, as in this layout, can be placed beyond the regular walls of the working room and do not offer any obstructions. Dark corners and inefficient areas are also eliminated.

HOW MUCH ELBOW ROOM?

In an aircraft factory where space was fixed but work fluctuated from nearly zero to capacity in short periods of time, the planning division adopted certain minimum areas of space per man upon which to base their peak employment. After considerable experimentation the figures given here were found to give maximum efficiency for the work to be done.

Once established, preparation of cost figures for bids on new work and determination of production possibilities for new work were simplified. These areas also provided a convenient basis for changes in shop arrangement and planning routines.

The allowance of 100 sq. ft. per man for assembly purposes shown here in Fig. 28 was for structural assembly other than assembly of airplanes. The allotment for assembly of a small

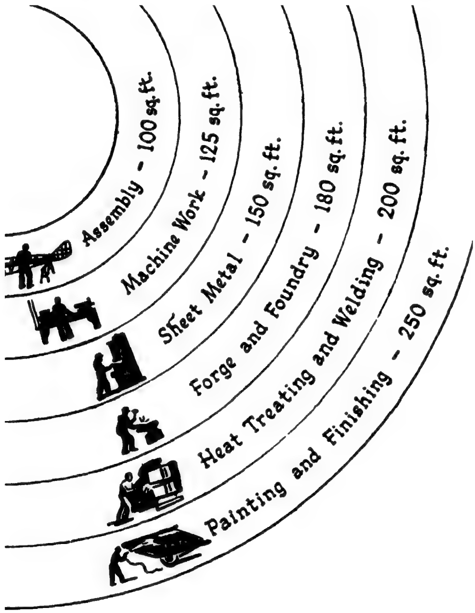

FIG. 28.—An approximate average of the floor space needed per employee for various operations serves as a guide in shop layout.

plane was 275 sq. ft. per man and for a large plane 325 sq. ft. per man. For the fabric- and panel-covering shop an allotment of 200 sq. ft. per man was made; 225 sq. ft. per man was allowed in the woodworking shop.

Requirements Vary.—Areas per employee will vary for different manufacturing concerns for several reasons. First, they will be affected by the amount of work that a company has for each man. If the amount of work on hand involves the deposit of partially finished material in various portions of the shop while awaiting a man to work on it, space must be allotted accordingly.

The type of work to be done also influences the amount of space required. For example, if a man were to be working on sheet metal, it might be possible for him to bend, drill, and then rebend or form to another shape all in one place in the plant. On the other hand, if a man is expected to do several diversified jobs, the required space is increased accordingly. Space per man goes up when more machines are required to do a job. Once having established a plant to do certain work, any loss in the quantity of the work, but not its type, results in an increase of space per man. Any plant which is laid out in a building constructed for other purposes will find itself generally with more space than is economically necessary for each employee.

These figures, while admittedly general, should serve for preliminary calculations in the layout of new shops or the layout of a shop in an old building. The areas required may then be increased or decreased, based on the judgment of the shop superintendent as to the type of work to be done and the method by which the work is to be accomplished.

Although these figures concern aircraft work, it is quite probable that the estimates for the machining operations would serve fairly well in the average shop. The spaces allotted for both assembly and painting are probably larger than would be needed in most shops. The figures will, however, serve as a basis for other estimates.

HOW ONE JOB SHOP MAKES MONEY

The secret of the success of the Boyar-Schultz Corporation, according to Harry Boyar, their superintendent, is the constant replacement of old equipment, high wages to first-class mechanics, and efficient shop layout.

As a jobbing shop is usually in the position of competing with its customer, the more efficient the customer the greater the competition. The contract shop must do the work more quickly and cheaply than the manufacturer can do it and with satisfactory quality. Otherwise, the manufacturer will set up his own department to do the job. Price becomes secondary when a high-quality product can be counted on for delivery in a reasonable amount of time.

Beginning business at the crest of the wave in 1929, this shop successfully survived the lean years primarily because it followed certain practices which are not new but may bear repeating.

First of all, they are firm believers in replacing machine tools as soon as others with better performance are available. Delivery is speeded up and quality improved by using the fastest and best tools on the market. For example, two jig borers less than two years old were replaced by new ones because of their superior performance over the previous model. Labor cost on individual parts is cheaper and the 10 to 20 per cent increase in production alone will pay for the machine in two years. Right now over 60 per cent of the machines are less than two years old. The remainder may be up to five years old because they are of the type which is pretty well standardized.

This modernization program is made easy in that they take a minimum loss on traded-in machines because good care is taken of them. Strict rules have been established so that all men keep the machines spotlessly clean. They found that telling the men occasionally wasn't enough, so they made etched brass plates which read, "If you are too good to clean this machine, you are too good to work here." These are attached to each machine where they cannot be overlooked and are effective. So that any grit and particles will have a chance to settle out of the air before reaching other machinery and motors, the grinders are grouped at one side of the shop.

Quick delivery is often demanded on work which normally would require a week's time. To satisfy this demand, two shifts have been kept on throughout the company's history. In slack times the night shift was small but it enabled them to give quick deliveries then and served as a nucleus for expansion when business improved. Furthermore, the two-shift system makes possible a rapid expansion to a three-shift, 24-hr. day when the factor that sells the job is delivery on short notice.

Delays arising from ordering and getting materials are not a last-minute complicating factor. All kinds of tools are kept on hand in sizable quantities. Large supplies of a wide variety of steels are always maintained in spite of the nearness of suppliers.

From the standpoint of making a quality product, it has been found profitable in the long run to pay top wages. This policy

ensures getting the best mechanics and also serves to stabilize labor turnover. The extra cost is chiefly absorbed by the better quality of finished work and less reworking to meet final inspection requirements. Better workmen also waste less time on a job. The employment of high-grade men also eliminates much supervisory, inspection, and other management expenses which cannot be calculated.

The value of each man and the cost of each job are checked by a simple card system. Two cards are issued to the shop for each job. One card is kept by the foreman; the other stays with the job, and the workman enters his time on it each day. He also turns a ticket in to the foreman giving the job number and the hours spent on it. The foreman records the hours on his card. If too much time is being consumed the foreman checks immediately. Here, again, the employment of quality labor pays dividends because no conscientious man will accumulate hours which he knows should not be necessary. His own entries of the time consumed on a job will reduce waste and speed up the work.

The office also keeps a spoilage card for each man. This card shows date, amount, and cost of all work spoiled. Ratings are given periodically according to this record. Raises and layoffs are based on these ratings.

Departmentalization.—When a job shop makes everything from bobbins for industrial sewing machines to printing presses, tools, and dies, in a space of less than 30,000 sq. ft., some maneuvering is required to get the desired rapid production. Departmentalization involved a tool-and-die division, a production division, a special manufacturing division, and a punch press division. In these divisions machine groupings were finally settled upon as the best means of saving space and expediting work. These are not theoretical divisions for purposes of management but mean a definite shop arrangement. While not separated by walls each division has a definite shop location.

Located for Light.—Tools and dies are made at one end of the shop. This division is located for best day-around lighting. Machine tools are at the center of a double row of work benches. All machine tools are grouped according to type: bench lathes, milling machines, drills, and so on. One branch of the overhead handling system runs along the aisle between the benches and

machines. It has sufficient capacity to handle dies weighing up to 10 tons.

The same arrangement is repeated in the production department and in the special manufacturing division. The production division corresponds to a regular jobbing machine shop in which are handled miscellaneous jobs, while the special manufacturing division handles mass-production work such as the contract for thousands of sewing-machine bobbins just completed.

The punch-press department is separate from any of the other production groups. It is used for quick delivery jobs. Presses turn out work cheaply by using inexpensive dies by a method similar to that used in other shops.

An inspection crib has been placed next to the shipping floor. It was found that a complete assortment of equipment for inspection pays for itself. Hardness and dimension tests are performed here. Etching tests for grain and cracks are an essential part of this work. A large percentage of inspection is done in this crib with very little being done in the shop proper.

After trying several locations it was found that best results were obtained with the Jones and Lamson comparator and the Zeiss instruments by placing them in a dustproof darkroom at one end of the shop near the grinding department. Walls are painted a dark gray which are less depressing than a black finish, especially if an inspector has to work in such surroundings for several hours at a stretch.

Heat-treating facilities are located on a balcony floor out of the way of machine-shop activities. Parts are hardened or otherwise heat-treated in four types of furnaces: artificial atmosphere (Vapocarb), liquid bath using salts of various kinds, semimuffle-type electric, and carburizing. Tools and dies are treated in the Vapocarb furnace. Drawing is done in a Lindberg Cyclone furnace.

The place of heat-treating in this shop and the reason for placing contour instruments near the grinding department are illustrated by the following procedure for making a tool:

1. Finish-machined in the tool and die division with sufficient plus tolerance for a final grinding operation.
2. Hardened and tempered.
3. Tested for hardness in the inspection crib.
4. Finish-ground in the grinding department.

5. Checked on Jones and Lamson comparator for form and outline.

6. Redrawn in Holden Hi-Speed case.

The last step has been found very desirable as it gives tools a marked increase in resistance to abrasion and useful life for a low added cost.

Executives Next to Shop.—It is essential in a group of this size that contact between department heads and shopmen be

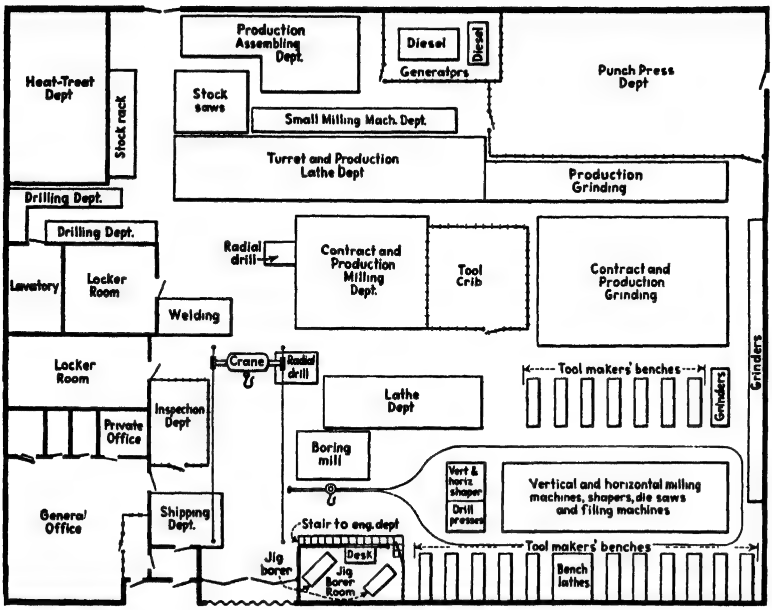

FIG. 29.—The shop has been laid out for four kinds of work: tool and die, production, contract, and special low-cost punch-press work.

easy. It is just another factor that reduces elapsed time in completing a job. For that reason the president, the shop superintendent, the sales manager, and the chief engineer are not hidden in offices. All occupy space in a common office next door to the shop. The designers on the second floor above the shop have direct access to the tool and die division, which eliminates more waste motion. This arrangement makes for pleasant relations throughout the company. The shop layout is seen in Fig. 29 with all departments named.

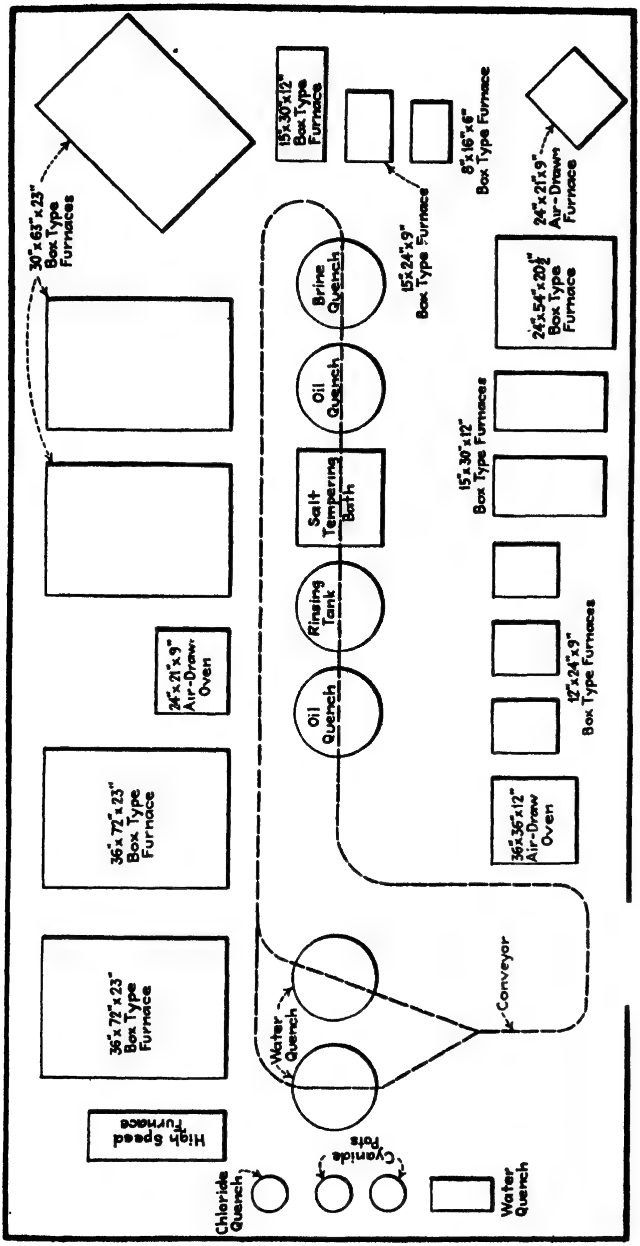

FIG. 30.—Heat-treating room for shop tools.

HEAT-TREATING SHOPS

While no general rules can be laid down that will cover all steels and conditions, a general knowledge of the way in which firms with wide experience handle the problems of heat-treating will serve as a guide. Until experience teaches better methods, it is wise to follow the suggestions of the maker of the steel in question. It is to his interest that you get the best results possible, and he will do his best to assist in every way.

The layout of the heat-treating department and the equipment used will vary widely according to conditions. The same layout will rarely suit two shops exactly. But many suggestions can be

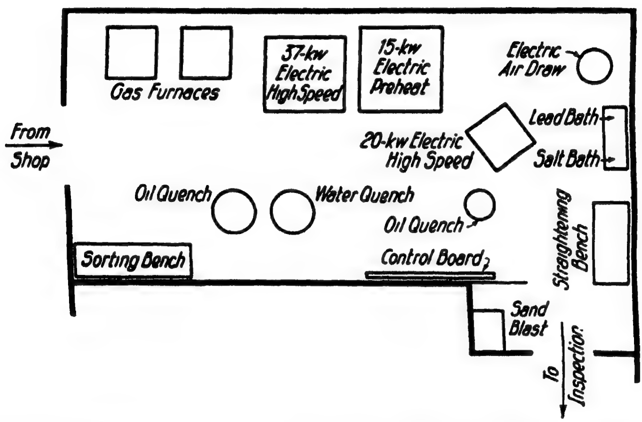

FIG. 31.—Compact heat-treatment plant for diversity of accurate cutting tools.

had from those whose methods have been successful in their own cases. For this reason we show the heat-treating room for tools in the Schenectady plant of the General Electric Company, the details being given by R. H. Mighell, in Fig. 30.

The layout, Fig. 30, gives all the necessary details. There are 14 box-type furnaces of different sizes, 3 air-drawing ovens, one high-speed furnace, one salt-tempering bath, two cyanide pots, one chloride quench, and a series of water, brine, and oil quench tanks convenient to the furnaces. All equipment is electrified but the layout will serve for other heat. Monorails and two electric hoists handle the work as shown, and the small box-type furnace is run continuously for emergency use. The cyanide pots are for case-hardening low-carbon steel. Each furnace has

automatic temperature control. The larger furnaces have automatic time switches to turn on the current so that the heat will be right when the men get to work. Modifications of this layout can be made to suit much smaller plants.

Heat-treating Small Tools.—A typical layout for a small heat-treating department is seen in Fig. 31, this being the shop of the Cleveland Cutter & Reamer Company. The work comes in at the left and goes to the sorting bench and from there to either the gas or electric heating furnaces, according to the work. There are two gas furnaces and three Globar electric furnaces of 15-, 20-, and 37-kw. capacity. There is also an electric drawing furnace with a basket 14 in. in diameter and of the same depth. A lead bath and a salt bath are also provided, with two oil-quenching tanks and one using water. The sand blast and straightening bench are near the exit where the work goes back into the shop. The 31-kw. furnace has a door 8 × 12 in. and is 18 in. deep, and the 15-kw. furnace is 4 × 8 × 12 in.

Shop for Commercial Heat-treatment[1]

Most commercial heat-treating organizations have grown from small beginnings, with equipment and space added piece-meal as necessity arose and circumstances permitted. It has seldom been practicable to lay them out in advance according to a comprehensive plan as would be done, for example, in preparing the heat-treating facilities of a large manufacturing plant whose requirements are predetermined.

The original plant of Metallurgical Laboratories, Inc., known under the trade name of Metlab Company, was destroyed by fire in 1937, necessitating removal to a new location. A thorough survey of available sites in Philadelphia and its environs was made for the purpose of locating quarters which would be suitable for the immediate needs of the business and would also provide for logical future expansion.

Finally buildings were found which consisted of three adjoining units, including approximately 32,000 sq. ft. of ground floor space. They are of steel, concrete and glass construction, almost completely fireproof and with ample light. Two of the units are of monitor design, about 50 ft. wide by 250 ft. long, 18 ft. high under the roof trusses and 36 ft. high at the peak. The monitor provides amply for ventilation and removal of heat and furnace gases. Between these twin buildings lies a third one of the same length, but 30 ft. wide, with a lower roof. All three buildings open on a driveway and a railroad siding at one end.

[1] By Horace C. Knerr, President, Metlab Company.

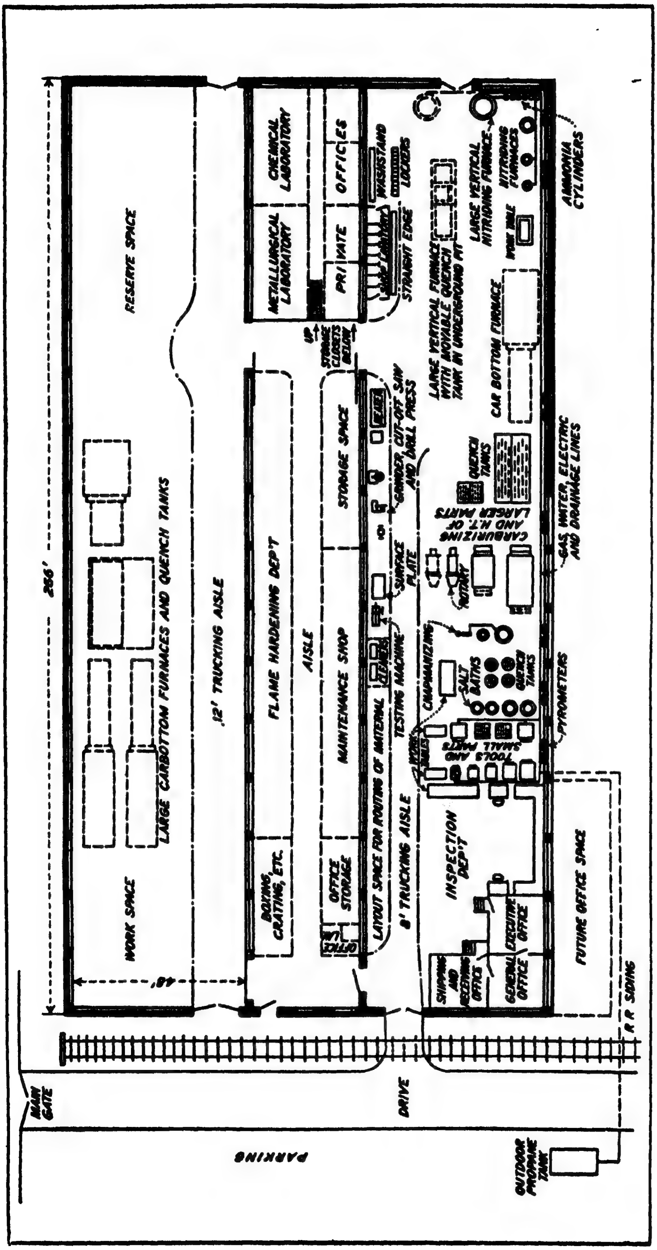

FIG. 32.—In this plan of plant arrangement present equipment is shown by full lines, projected equipment by dotted lines.

An effort was made to lay out the plant according to a reasonably comprehensive, but not too rigid, plan, which would provide for orderly growth and ensure good operating conditions at all stages. [The floor plan is seen in Fig. 32.]

Heat-treating operations and equipment have, to a certain extent, been departmentalized. Apparatus has been set up so that it can be moved and relocated with minimum effort.

Aisles for moving material and space for setting down work in process have been provided. A simple and orderly yet flexible arrangement for service lines and pyrometric equipment has been adopted. The office is located in the west or front end of the south building and is divided into three sections, shipping and receiving, general, and executive or supervisory. All material enters and leaves the plant at this entrance, therefore passing directly under the close supervision of the office where it is checked for quantity and condition and routed in accordance with purchase orders and shop orders. The inspection department lies adjoining the office so that all incoming and outgoing work also goes through this department. This feature is considered desirable in a commercial heat-treating business because of the close checking and rapid follow-up of a great variety of orders.

An aisle of truck width extends the full length of the building. On the left side of this aisle is an area 8 ft. wide reserved for depositing material and for certain auxiliary equipment. On the right side is a space more than 30 ft. wide in which the heat-treating furnaces are arranged in banks according to their function and size. These furnaces face on transverse aisles which communicate with the main aisle. Men's lavatories and lockers are at the far end of the building.

All service piping and wiring lie along the low, continuous wall beneath the windows on the south side of the building and so feed various bays from transverse communicating lines, leaving the floor and the aisles undisturbed. Service includes gas (propane), water for cooling, electricity and pyrometer lines. No compressed air is used at present, but space is available for airlines if later required. There is space for the introduction of fuel oil lines. At the bottom is a large pipe for carrying off cooling water drainage.

The various bays are laid out in line with the roof trusses and their supporting wall columns which are spaced on sixteen foot centers.

The first bay of heat-treating equipment includes small furnaces for tools and other small parts. Quench tanks are conveniently located opposite the furnaces so as to permit rapid quenching. Certain small quench tanks are carried on skids or wheels so that they may be moved closer to individual furnaces where this seems necessary.

Pyrometers controlling the furnaces in any given bay are located on the side wall so as to be clearly visible and readily accessible.

The second bay is for tempering furnaces and baths. Following this is a bay for small salt bath furnaces, cyanide pots and Chapanizing equipment, with their respective quenching tanks. These baths are hooded where necessary, with vent pipes extending horizontally out through the south wall below crane level.

Beyond this are medium sized furnaces for general work such as annealing, hardening and carburizing. Rotary carburizing and annealing furnaces will lie in this area until there is sufficient volume of such work to set up a bay for this purpose.

FIG. 33.—General view of furnace room.

The larger oven type furnaces in this section are of double end design, the rear end being closed with insulating brick readily removable, and space is provided for access to the rear end of the furnace. Provision is next made for larger car-bottom furnaces and accompanying quench tanks with their circulating cooling systems.

At the far end of the building is the nitriding department, including at present four furnaces, one of which is 12 ft. high for vertically nitriding long rolls and shafts. Ammonia is manifolded and piped to the various furnaces and each furnace connects with a vent pipe which carries exhaust fumes above the roof.

A large space in the center of the far end of this building is reserved for erection of a vertical heat-treating furnace designed for quenching aircraft structures and other long members which was a notable part of

the equipment of our old plant. This furnace will be approximately 4 ft. square by 18 ft. high inside, with the door at the bottom.

A good sized space is reserved for flame hardening operations now undergoing development.

Testing equipment includes a Southwark hydraulic testing machine, Rockwell and Scleroscope hardness testers and the new Knerr-King portable Brinell hardness tester.

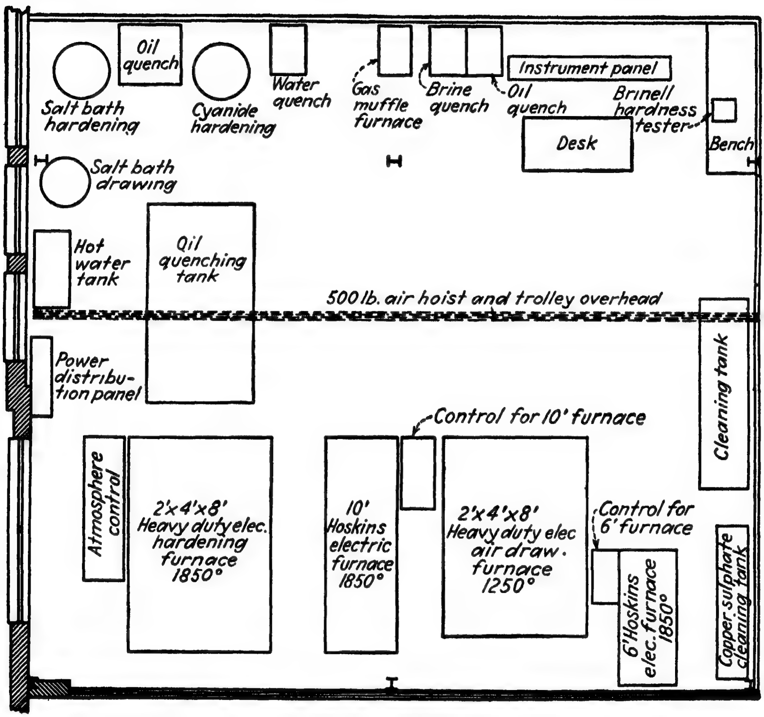

FIG. 34.—Only 38 ft. wide and 40 ft. long, this new heat-treating department is compactly arranged to meet the exacting specifications of its product.

One of the most important requirements in commercial heat treating practice is that of straightness, especially of long, slender members. Two mechanical surface plates 4 × 6 ft. in size provide a convenient means for checking the straightness and flatness of small and medium parts and are handy in many other ways. In addition to the surface plates, there are several planed H-beams ranging in length up to 20 ft. for checking the straightness of long, slender parts and a roller base for the indicator testing of shafts.

A general view of the furnaces can be seen in Fig. 33.

Heat-treating Airplane Parts.—For treating the steel parts used in airplanes, the Boeing Aircraft Company, Seattle, installed a heat-treating department 38 × 40 ft., as shown in Fig. 34. This was made to handle chrome-molybdenum S.A.E. 4130, chrome-nickel-molybdenum S.A.E. 4345, nickel steel S.A.E. 2330, and S.A.E. carburizing steel 2515. It is also used in annealing 17 S and 24 S aluminum alloy. The parts handled include spar chords, gussets, cylinders, struts, landing-gear parts, trunnions, fittings of all kinds, terminals, retracting screws, bolts, and tools.

Every provision is made to handle the various parts in the best manner with hoists, trolleys, steel tables on casters, and other handling devices.

Oil-furnace Capacity

In production and cost estimating it is frequently important to have a fairly close estimate of the capacity of various oil furnaces as well as the amount of stock heated per gallon. Oil furnaces can be divided roughly into three classes:

1. Welding furnaces working at approximately 2900 deg. F.
2. Forging furnaces working at approximately 2200 deg. F.
3. Heat-treating furnaces working at approximately 1600 deg. F.

Stock going through these furnaces absorbs heat in various amounts, but it will not be far from average conditions if we estimate the heat pickup per pound of stock as follows:

1. Welding furnaces, 430 B.t.u. per pound.
2. Forging furnaces, 360 B.t.u. per pound.
3. Heat-treating furnaces, 260 B.t.u. per pound.

This heat, of course, is obtained from combustion of the oil, and the heat value of a gallon of fuel oil varies according to its composition. Probably the best average value for this is 140,000 B.t.u. per gallon. From this can be determined the output of various oil furnaces, assuming they are 100 per cent efficient—which most emphatically they are not:

1. Welding, 326 lb. per gallon at 100 per cent efficiency.
2. Forging, 390 lb. per gallon at 100 per cent efficiency.
3. Treating, 540 lb. per gallon at 100 per cent efficiency.

Efficiency not only varies between the furnaces themselves, but the efficiency of each furnace is changing constantly according to operator, air mixture, oil, humidity, and a dozen other factors. The results of a number of tests on average shop furnaces under ordinary running conditions indicate that the following efficiencies are a good approximation:

1. Welding furnaces, approximately 15 per cent.
2. Forging furnaces, approximately 25 per cent.
3. Heat-treating furnaces, approximately 40 per cent.

We can now find about what to expect from the average furnace in pounds of stock heated per gallon of oil burned. As the hourly oil consumption per furnace is generally known by the cost department, it becomes easy to estimate production and cost by taking the following round figures:

1. Actual welding output, 50 lb. of stock per gallon.
2. Actual forging output, 100 lb. of stock per gallon.
3. Actual treating output, 200 lb. of stock per gallon.

By figuring on the basis of gallons per hour consumed, both the rate and the cost of stock heated may be estimated in production pounds of stock per hour.

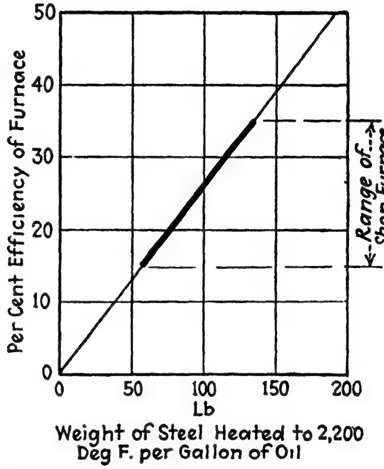

FIG. 35 —This chart can be easily made.

For those who wish to get closer estimates and who are in a position to get fairly accurate data for the particular furnaces and oil being used, it is handy to draw up a chart of the type shown in Fig. 35.

Cost of Electric-furnace Operation

Decision as to the kind of furnace to select for any shop depends, to a considerable extent, on the cost of installation and operation. The following figures are from tests made by Wirt S. Scott of the Westinghouse Electric & Mfg. Co. on furnaces installed at the Roanoke shops of the Norfolk & Western railway. There are three furnaces, as follows:

Preheating furnace:

Hearth area, 12 × 22 × 8 in. high.
Electrical capacity, 8 kw., 1 phase, 110 volts.
Range of operation, 400 to 1850 deg. F.

Hardening carbon steel:

Hearth area, 12 × 28 × 8 in. high.
Electrical capacity, 13 kw., 1 phase, 220 volts.
Range of operation, 1000 to 1850 deg. F.

Hardening high-speed steel:

Hearth area, 10 × 18 × 6 in. high.
Electrical capacity, 30 kw., 220 volts.
Range of operation, 2000 to 2500 deg. F.

The operation of heat-treating high-speed-steel blanks $\frac{1}{4} \times 1 \times 6$ in. consists in placing them in the 8-kw. furnace at a temperature of 1000 deg. F. and soaking them 1 hr.; removing and placing in the 13-kw. furnace at a temperature of 1600 deg. F. and soaking $\frac{1}{2}$ hr.; removing and placing in the 30-kw. high-speed-steel hardening furnace at a temperature of 2250 deg. F. for 5 min.

Chrome-steel die blocks are hardened at 1600 deg. F., quenched in oil, tempered at 950 deg. F., and cooled in air. Shear blades are hardened at 1450 deg. F., quenched in water, and tempered at 420 deg. F. Insert blades for reamers are hardened at 2250 deg. F., quenched in oil, tempered at 1050 deg. F., and cooled in air.

The record shows an average of 1400 lb. of tool steel at 60 cents per pound, a total of $840. Tools are reported to last longer, showing a saving of $280. A rough estimate was made as to the monthly power consumption of the three electric furnaces, based upon observed operating conditions over a period of 4 days. Such computations show an estimated monthly consumption of 6250 kw.-hr., which would cost, at an 8-mill rate, exactly $50 per month.

In the maintenance of locomotives, there are a large number of parts to be carburized, such as wristpins and bushings, equalizer

bushings, split-side rod bushings, brake pins, spring-rigging pins, knuckle pins, die blocks, and die-block pins. All of these parts are placed in nickel chromium boxes, and packed with crushed bone.

The parts are made of low-carbon steel to give maximum toughness and are given a case of $\frac{3}{64}$ in. The heat-treating is done at a temperature of 1650 deg. F. Two electric furnaces are available, each having a rating of 120 kw. capacity with an effective hearth area 42 × 56 × 20 in.

These furnaces are of the roller-hearth type with the rollers extending about 6 ft so that the boxes may be packed in position and rolled into the furnace This operation requires the services of two men. Two different sizes of boxes are used: 16 × 22 × 18 in. and 16 × 50 × 18 in Two large boxes, four small boxes, or one large and two small boxes constitute a charge.

The furnace is charged every afternoon at 5 P.M. Usually from 12 to 16 hr are required per heat, depending upon the weight of charge. An average charge will weigh from 1400 to 1500 lb. net of material to be carburized, 1100 to 1200 lb. of carburizing boxes, and approximately 500 lb. of crushed bone.

A test made on one of the furnaces to determine heating characteristics and power consumption showed the following:

	Pounds
Net weight of work	1436
Carburizing boxes	1148
Crushed bone	505
Total gross weight . .	3089

The parts heat-treated were miscellaneous locomotive parts, consisting largely of pins and bushings, weighing as follows:

Pieces	Pounds
700	525
162	183
75 .	51
17	55
12	144
10	350
4	128
Total 980	1436

Procedure

Furnace temperature at start	860 deg. F.
Operating temperature	1650 deg. F.
Time in	5 P.M.
Time out	6:10 A.M.
Time for furnace thermocouples to reach 1650 deg. F	2 hr. 45 min.
Time furnace is held at 1650 deg. F	10 hr. 25 min.
Total time heat applied	13 hr. 10 min.
Kilowatt-hours consumed in reaching 1650 deg. F.	328
Kilowatt-hours consumed after reaching 1650 deg. F.	400
Total kilowatt-hours consumed	728
Gross pounds of material per kilowatt-hour	4 25
Net pounds of work carburized per kilowatt-hour	1 97
Cost of power per charge at $0.008 per kilowatt-hour	$5 82
Net cost of power per pound of material carburized	$0 00406

Tests made on carburized parts show a uniformity of case regardless of the location of the part in the furnace or in the box. This uniformity had not been obtained with the old furnaces.

FLOOR FOR 100-TON MACHINES

Erecting facilities play an important part in the production of heavy machines. Both the erecting floor itself and the equipment for handling heavy units must be adequate. When William Sellers & Company decided to convert a foundry building into an erection shop for handling machines that weighed up to 100 tons and were 70 ft. long, the floor came in for particular attention. The building had a clear span of 76 ft. and two 40-ton cranes. In it would be erected such heavy units as plate planers, turret-track turning machines, car- and driving-wheel lathes, planers up to 72 in., and other large units.

The floor in this shop would have to be kept level and free from vibration. An 18-in. concrete floor was selected. In it 8-in. channels were set in pairs to give T slots for holding down bolts. These channels extended 3 in. above the concrete, to allow for a wood-block floor level with the top of the channels.

A power shovel excavated the floor area to the proper depth, and a 6-ton roller was used to ensure a solid surface. Because the floor was not designed as a beam, only temperature reinforcement of 6-in. welded wire mesh was needed. This was blocked up 3 in. from the lower surface before the concrete was poured.

Small concrete piers were constructed to support the channels and to keep them level and in correct position. The concrete

was poured in sections not exceeding 32 ft. in either direction, with ½-in. premolded expansion joints between sections. Eighteen-inch curb forms outlined the sections. The concrete used has 2000 lb. per square inch capacity. Channels are 8 in. × 21 ft. and weigh 25 lb. per foot. They were bolted together with separators and the pairs tied together with ¾-in. rods, spaced 5 ft. center to center. Space between flanges was left clear for a depth of 3 in. to accommodate T bolts. This floor will support a machine weighing 100 tons even if supported at only four points at least 3 ft. apart.

Wood-block flooring is of Southern yellow pine treated with 6 lb. of Kreolite oil per cubic foot. It will sustain static loads

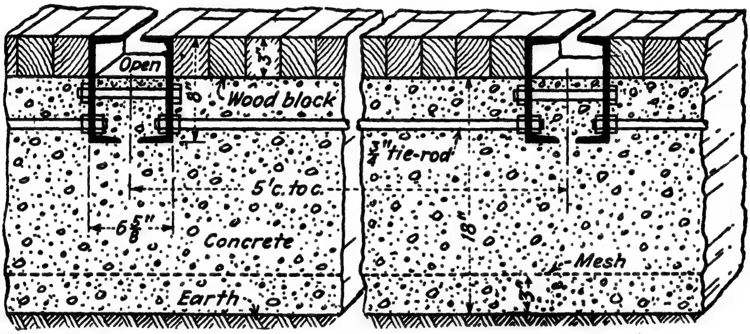

Fig. 36.—Foundation for an erecting floor for 100-ton machines.

up to 90 tons per square foot. Block flooring can be taken up and replaced easily, does not damage tools or parts dropped by accident, has long life, and is warm and easy on the feet. Details are shown in Fig. 36.

BUILDING AN OFFICE FOR THE SHOP

The problems confronting the Landis Tool Company in building a new office building were so similar to those of many other plants that their solution should be of service to many others.

The carrying out of building operations presented a real problem, for there was no available space that could be used temporarily as an office. It was fortunate, however, that the ground floor of the building which housed the executive, sales, accounting, and purchasing offices was not used for office purposes. Although the building was moderately old, its steel framework

was found to be entirely satisfactory for use in a modern new building.

The ground floor of the building was emptied, and work got under way. Everything was torn out but the steel framework, while at the same time a 32 × 60 ft. addition was started. When the new outer walls rose to the old outer walls of the second floor these walls were removed in sections, the new walls immediately replacing them. At last the old roof was reached and an entirely new roof took its place. All the while the second floor was being used, noise and dust notwithstanding. In the meantime, work had been proceeding on the inside of the new ground floor.

As soon as the ground floor was finished, offices were moved down to their new permanent quarters. This was followed at once by a complete gutting of the second floor. When it was finally completed, the engineering department, which had been housed in an adjoining building, moved in.

Executive offices are air-conditioned by a plant installed in the basement. Drinking water for all offices is cooled by a small refrigeration unit adjacent to the air-conditioning plant. Venetian blinds are used throughout, thereby making possible close regulation of natural light. All partitions are of glass. Indirect artificial light is used, illuminating engineers having carefully determined requirements before installation. No longer are the conventional desk and table lights seen—they have gone the way all obsolete equipment should go.

An abundance of electric outlets makes it possible to plug in electrically operated office equipment practically anywhere without extensions. The executive offices are finished in walnut with tables and leather covered chairs to match the woodwork; elsewhere the finish is a soft olive green. Asphalt tile flooring is used in the ground floor offices of the new building.

The new engineering department, Fig. 37, completely revamped, occupies the entire second floor of the new office building. Instead of housing the entire department in one large room, numerous smaller offices and drawing rooms are now used. In these subdepartments are the 74 people designated to engineer and detail machines of various types built by the company.

Lighting Planned Carefully.—Wooden floors are used throughout in the new layout. Because much of the work is done by the draftsman in a standing position, these wooden floors were con-

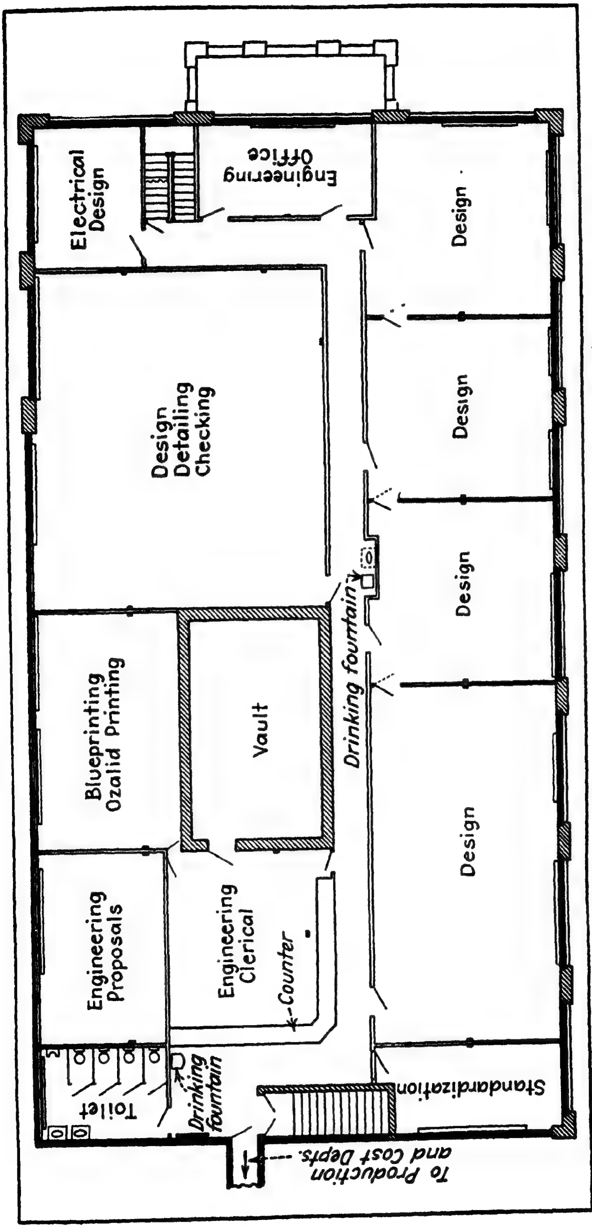

FIG. 37.—The designers have private rooms in this office building.

sidered as contributing less foot and leg fatigue than cement floors, thereby increasing the men's efficiency. To overcome the necessity of both overhead and individual board lights, the same indirect lighting arrangement was installed as in the lower offices. White ceilings and white walls above a wainscoting of soft green reflect the correct amount of light, making unnecessary the use of eye shields.

One or two large Emmert vertical drawing boards 6 × 14 ft. in size flank one side of each design room. It is interesting to

Fig. 38—Full-sized layouts are designed on the large boards in the background while subassemblies and details are made on the inclined boards in the foreground.

note that the counterweights for these heavy boards are not behind the boards as formerly but out of sight in the space between the ceiling and the roof above, the cables for the counterweight passing through the ceiling. At these boards the head designer or group leader lays out designs full scale while behind him are grouped smaller boards for the designers of subassemblies and the detailers. Thus the department is self-contained. The smaller inclinable Emmert boards, standardized to sizes 28 × 42 in. and 34 × 48 in., are mounted at an angle of approximately 22 deg. At these latter boards the men can either stand or sit,

the boards being adjustable to any desired height. The backs of the boards, counterweights, ropes, and pulleys are painted with aluminum so as to increase light reflection. See Fig. 38.

Fireproof vault walls extend up through the approximate center of the engineering department thereby making it easily accessible to each individual design room. Directly outside the vault is the "counter," a long continuous table with inclosed front extending at right angles around two sides of the room to form a separate office. At this counter all transactions are made

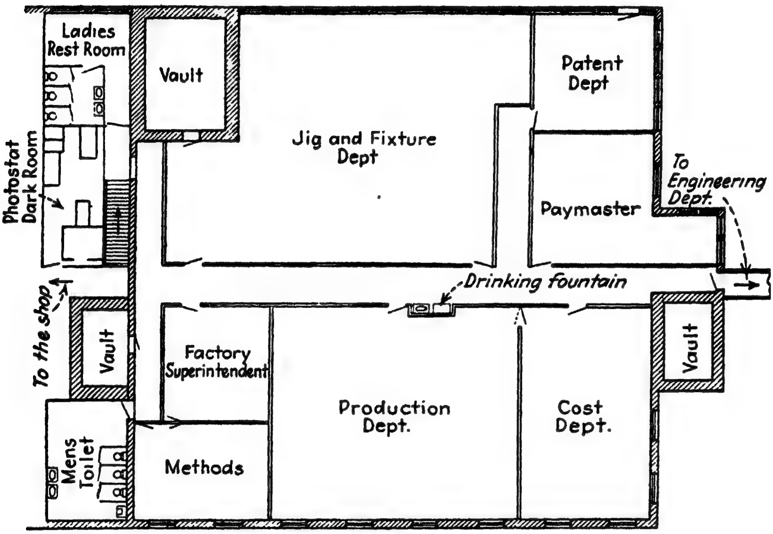

FIG. 39.—These departments join the engineering office.

between the various engineering departments and the shop, making it unnecessary to disturb others in each design office. The counter is constructed in skeleton form to accommodate numerous three-drawer steel cabinets for filing all active parts lists and special orders. In the space so enclosed, all the clerical work pertaining to design is done, parts lists typed, changes made and recorded, repair orders received and dispatched, blueprints, ozalid prints and photostats issued, and parts for special machine orders specified. Being centralized, all drawing supplies are also kept here.

A new continuous blueprinting and washing machine was installed in the new blueprinting room. Photostating was

formerly done in this department, but this was found to be unsatisfactory. The equipment is now in a separate dark room in which the printing is done at specified periods.

A building connected to the new one by an enclosed passage contains the tool and fixture drawing room, production and cost departments, shop superintendent's office, methods department and also the patent and paymaster's departments as in Fig. 39. In one corner of the tool and fixture department are located the tracers. Whereas the production and cost offices were originally located on the ground floor of the shop proper, they are now more advantageously situated, being adjacent to the designing department with which most business is transacted.

CHAPTER 3

SHOP EQUIPMENT

MACHINERY

Selecting machine and other equipment for the shop requires careful consideration. Even where ample capital is available, unwise or unnecessary expenditure adds to the overhead, affects shop costs, and, in competitive bidding, may lose a contract.

Every good mechanic loves fine, new machinery, just as every driver loves a new car. But just as "every car on the road is a used car," so every machine ceases to be new the minute it is put to work. Many feel it advisable to save the initial depreciation of new equipment when it can be bought in good condition at a substantial reduction. This applies primarily to small shops with limited capital but is not confined to such cases. The advisability of this depends on whether the used machine will serve the purpose practically as well as a new one, as is often the case with an automobile.

Used Machinery.—Sales of used machines often enable the original owners to buy still newer machines that will pay them in increased production. The used machine, on the other hand, still has many hours of useful work that may serve the smaller shop as well as a new machine. In fact, many small shops have been started with machinery that was hopelessly out of date for a production shop, but had this not been available, the small shop might never have been started because of the lack of capital.

Selecting machinery, whether new or used, requires the best judgment of its adaptability to the work as well as its condition. Some fairly large shops have considered it advisable to buy used machinery for roughing operations but to get new machines for finishing. Then too, some used machinery, with a little rebuilding, may serve as well as, or better than, some new machines. One very large plant that buys thousands of dollars worth of new machines every year has a battery of screw machines that are

over forty years old. These machines are thoroughly rebuilt every few years and kept in first-class condition. They are retained at considerable expense because the management feels that for their particular job no other machine equals their performance in either speed or accuracy. They have hundreds of other screw machines of the latest designs but prefer these for this special job.

Rebuilt machinery has made a place for itself in modern industry. Sometimes the rebuilding is done by the maker of the machine, but more often by wide-awake dealers. *In the last analysis all new machines are built on used machines.* Your own good judgment, plus dependence on reliable dealers, can save considerable capital in equipping a new shop or adding to the capacity of an old one. Deciding whether to rebuild old machines, to buy new ones, or to use second-hand machines requires good judgment on the part of those responsible.

No rules can be given for the purchase of machinery or equipment. But a few suggestions based on the experience of successful engineers may be of value. "Buy all machinery from reputable concerns, whether makers or dealers." This is particularly advisable in buying used machinery. Since new machinery is usually sold by dealers, be sure to select one with an outstanding reputation. In fact, reliable dealers can be of great assistance in equipping a new shop or in adding to an old one. They can frequently make legitimate concessions to move stock by taking machines in trade that have served their purpose in the shop.

Machine Economy.—Machines that will not produce economically, either as to quantity or quality, should be sold or junked. Age alone, however, has little to do with the value of a machine in the average shop. In mass production the saving of a fraction of a cent per piece turned out will often pay for a new machine in a year or even less. Here an improved machine may make the previous model obsolescent as soon as the new one appears. But the older machine may be a paying investment for some other shop where machine overhead cannot be written off as rapidly as in the big plant.

In the average shop, and particularly in contract, job, and railroad shops, there is seldom any opportunity for rapid liquidation of the cost of new machines. In spite of this, however, it frequently happens that new types of machines, such as jig

borers, make it possible to do better work in so much less time that they become a necessity, even though there is not enough work to liquidate their cost for several years.

In too many cases machines already installed are producing far less than they could if proper attention had been given to arbors, drills, cutters, and fixtures. It often happens that foremen and operators are so intent on the particular job in hand that they overlook opportunities for increasing production with the machines already available. For this reason it is often possible for an outside engineer to see where production can be materially increased with the equipment already available.

Keep Machine in Best Condition.—Proper selection of cutters for milling and other work and care in sharpening and in protecting their cutting edges will show great economy in any shop. The importance of cutting edges is too often overlooked. In many cases the production rate of a new machine drops after the machine demonstrator leaves the shop. Frequently the cause of this is the fact that when the tools are reground, cutting angle and clearances are not maintained as originally designed.

It is safe to say that few, if any, men can grind a milling cutter, form tool, reamer, or drill as well by hand as can be done on a good machine in the hands of a good tool grinder. Taps are too frequently ruined by so grinding the flutes as to change the rake angle and thus interfere with the cutting and the clearance.

It should never be forgotten that the cutting tool limits the production of any machine from the cheapest to the most expensive. The more costly the machine the more care should be taken to see that its tools are in the best possible condition at all times.

There are many places where new, or at least better, machines are necessary and will pay for themselves within an economic period. But before this can be fully and honestly decided, it is necessary to be sure that the machines already in the shop are being used to their best advantage.

In one small repair shop that has made money consistently, not a single machine is less than fifteen years old. But every machine is kept in excellent condition by frequent overhaulings to see that bearings, slides, and feed screws are in good condition. This keeps the men busy in slack times and holds the force together for long periods. As a result the shop has the reputation of

being able to repair any kind of a breakdown and gets work for miles around.

On the other hand, too many shops do not count the cost of repairs and frequently use machines that lose money for them every time they are used. Practical management must decide when to scrap a machine or to spend money in keeping it in order.

Evaluating a Machine.—In determining the economy of purchasing a new machine or other equipment, one must guard against being carried away by *percentages* in time saved. It is much safer to count the savings in dollars and cents and to see how long it will take the machine to pay for itself. In so doing the probable yearly, or even the total, demand for the product should be carefully considered. For, unless the demand is likely to continue it may be cheaper to pay a little more per piece than to tie up capital in a new machine. This, of course, assumes that the machine is being considered for a certain job. If it is one that can be used on a variety of products, only its total usefulness need be taken into account.

It should not be forgotten that in some cases labor is less expensive than machine investment. For labor can be shifted to different jobs much more readily than a machine.

EQUIPMENT TO FIT THE SHOP

The selection of equipment of a shop depends necessarily upon the type of shop operations to be carried on; whether the plant is to handle general machine and repair work or to be a contract shop, specializing in certain lines of work, such as tool and die building; a grinding specialty shop; a screw-machine products plant; or perhaps a sheet-metal and stamping shop. This classification could be extended considerably, but the point is that all these shops require certain standard types of machine tools regardless of whether these are for regular production jobs or for tool work. Some shops prosper on special or repair jobs that are likely to come to almost any shop conveniently situated and equipped for the class of work and the size required by the customer.

Some shops, because of location in rather remote sections, have to equip with some heavy tools as well as light ones. Others can select their equipment along more general lines and send out to some other plant any job which is outside their own field. This

may be either because of its unusual size or because it requires the use of special machinery not already in one's own shop.

Many types of shops for many purposes could be illustrated under this general head. Typical shops and their equipment have been shown in Chapter 2. These are sufficient in number and variety to give a fair idea of what a shop's equipment should be to place it in the group of metalworking plants which engage in some form or other of machine work, tool work, or parts manufacture. Others will be given here.

Contract-shop Equipment

Contract shops in which high-grade work is done must have equipment on which accurate work can be done and at the same time it must be flexible enough to cover a wide variety of work. In addition, the fluctuations of such a business may make it necessary to expand the working force from 50 to 250 men within 30 days, especially in large manufacturing districts with work of a seasonal nature, as with automobiles. Estimates must be accurate as well as the work, which requires the best of management both in shop and office. The experience of F. Jos. Lamb, head of a large tool shop in Detroit, is of great value in this connection, and is discussed below.

A wide range of work must be covered—design of the die to meet the customer's print of the part, making the foundry pattern and the casting, using Keller machines for forming the dies. The dies are tested before release to the customer. Considerable time may be saved where these diverse operations are included in one plant. These advantages may sometimes be secured by having a company to make its patterns located next door and a foundry company located across the street. Floor tracks running to all heavy machines with cars to the height of the machine-bed plates conserve crane service and eliminate heavy lifting of dies, tables, and rotating devices.

In addition to the usual run of shapers, lathes, grinders, radial drills, and thread millers usually found in tool and die shops, the outstanding equipment are engraving machines, jig boring machines, and horizontal boring machines.

Jig-boring Equipment.—The jig-boring machines used in this plant are furnished with slots at right angles to each other, conforming to table travel, in which are placed circular end

measures, including a micrometer. These end measures in each case act against a graduated dial, which with the micrometers in the train of end measures permits measurements to a "tenth." While this is standard equipment for up-to-date tool shops, adaptations and additions in the form of a rotating bed plate to handle holes drilled in a circle, and an extension table to handle large work, both of which are bolted to the standard slide of the machine, make it adaptable to a wide range of work where extreme accuracy is required.

A further case of adaptability and flexibility in jobbing equipment is exemplified in the use of a recently developed drill speeder in conjunction with a horizontal boring machine. The machine itself has a range of speeds from 20 to 600 r.p.m. In drilling small holes and in working with white metals, such as aluminum, higher speeds are necessary. By placing this small compact drill speeder in the machine spindle, each speed of the machine is multiplied by four so that the range of speeds now runs from 20 to 2400 r.p.m., thereby greatly increasing the range of use for drilling and light milling.

Use of this drill speeder on a two-spindle drill for drilling holes in a connecting rod for domestic refrigerators further illustrates the flexibility and economy secured in machine equipment by its use. Two holes were to be drilled in the forging, $1\frac{1}{2}$ in. in one end and $\frac{5}{16}$ in. in the other. One motor drives both drill spindles. While 250 r.p.m. was satisfactory for the larger hole, it was not fast enough to secure maximum economy for the smaller hole. By using the drill speeder on one spindle for the smaller hole, the rod could be drilled complete in one setup end at the proper speed conforming to the size of the drill. Thus the range secured covers not only proper speeds for different drill sizes when drill spindles are in multiple but enables material ranging from steel to aluminum to be handled in the same machine.

Accurate Depth Facing.—An adjustable sleeve for depth facing developed in our shop permits adjustment to 0.0015 in. for this class of work and eliminates measurements for depth except for cutter wear. This device, adjusted easily and quickly to the machine spindle, secures economies in reducing operator time. Adjustment, by turning the ratchet may be made without removing the sleeve from the spindle. The splines in the sleeve are cut in an automatic spline miller.

It has been the practice for some time for jobbing tool and die shops to job out in turn the die-design work. The print of the part from the customer is turned over to the design jobber who makes the die design, which in turn is approved by the customer, after which the casting is made. The die blanks are then placed on a Keller machine to be formed from the wooden models. Presses for the tryout are provided in the jobbing shop, or if the range of work is too large for these tryout presses, the tryout is done in the customer's plant. To receive a die O.K. on the second piece run off is not infrequent, so accurate has automotive die work in the die shops become. This is no small task when it is considered that a set of dies for a radiator and grille may run as high as $35,000.

Tool and die inspection, in addition to accuracy in machine equipment and flexibility in operatives and supervision, is an essential. Sets of gage blocks are in use in all the better shops. While expensive, these and similar devices insure that tools and dies are accurate before delivered to the customers, a requirement in the independent shop.

While overhead in the form of systems is something to be avoided as far as possible, yet some devices prove their worth. In the Lamb shop a progress report is maintained on all jobs in conjunction with the job-cost system. The estimator estimates the hours of work required, which becomes an important cost criterion. Three or four times weekly—in many cases daily—the foreman estimates the percentage completion of the order. This is entered in its appropriate space on the progress report and permits a comparison with cost figures. If the job is 50 per cent completed and 75 per cent of the estimated cost has been expended, an opportunity is given to check into the remaining work for purposes of reducing the cost.

Purchasing agents of prospective customers are interested in knowing the range of equipment afforded by the independent tool and die shop. The Lamb Co., has a printed list of all equipment in the shop. Part of the list is shown on page 112. A copy of this list in the drawing room helps the designer and also the planner.

It is a policy in this shop to buy new machine tools only. Requirements of accuracy on the kind of work done are so strict that used machines would have to be entirely rebuilt.

One of the great advantages of the jobbing tool shop is that skilled all-round toolmakers prefer this kind of work. This means that the operating force, both executives and operators, are versatile, and that operations can be handled with the maximum of flexibility. On the other hand, the fluctuations in business are so considerable that it is difficult to take on apprentices. By the time a boy taken on in good times would have received his training, the business cycle might have swung from peak to trough, and there would thus be no work for him when he was ready for it. A further handicap on training in such shops is that the low overhead provides little for supervision. The men in the shop must therefore be of the type capable of carrying on their work with a minimum of attention from the executives.

Precise, accurate work on modern equipment, coupled with flexibility of force and versatility of the individual are the stock in trade of the contract die and tool shop. They are the factors that have made the good shops in this field indispensable to the production industries.

Equipment.—Part of the equipment of the Lamb shop follows:

2 Keller-type engraving machines.
3 horizontal boring machines.
2 jig borers.
1 vertical surface grinder.
4 internal grinders.
1 tool and cutter grinder.
1 plain cylindrical grinder.
3 universal cylindrical grinders.
6 surface grinders.
1 disk grinder.
12 toolroom lathes with attachments.
3 turret lathes.
6 radial drills.
3 vertical milling machines.
4 knee-type milling machines.
1 hand milling machine.
16 shapers.
2 slotters.
10 upright drills.
4 sensitive drills.

Miscellaneous presses, flexible shaft tools, portable tools, thread and spline millers, keyseaters, and gear shapers.

Hardening and inspection equipment.

Drafting boards, with parallels: 50-man capacity.

Equipment for the Small Shop

Unusual Equipment.—The small shop, whether on general jobbing or toolmaking, usually reaches a point where it possesses certain very useful tools not commonly found in production lines but of special value in some classes of work coming to the specialist. Some of these repair shops handle a type of work requiring very large machine tools and find these are often used in handling the unusual kind of jobs that are not seen in general plants. One old firm doing work for marine and mining companies still uses a big pit lathe that has paid for itself many times over, although it would hardly be practicable to replace it with a modern tool of the same size. This is a case where modern high speeds and feeds are not so important as the ability to swing a job that cannot be handled by any other machine in the community.

A machine shop in an agricultural section has long used a grinder much larger than commonly required (outside of railroad shops and steel mills) for handling miscellaneous work requiring plenty of room between centers.

There is a well-known tool shop that has had for years a big vertical slotter which is a veritable money saver to customers with large work. Although tools of this type and extra capacity are not commonly found nowadays outside of railroad shops and marine repair shops, the toolmakers running this place have made continuous use of the big vertical machine for doing such work as shaping out big molds for battery boxes and doing other work which would otherwise have to be handled on planers with extension bars or other makeshift devices.

One small shop has an old 300-ton hydraulic wheel press which was bought from a railroad and which has proved to be a gold mine. It attracts work from a large radius, for no other shop has equipment to remove and make large force fits. Unusual facilities of this kind attract work that would not be secured otherwise.

Attachments for Standard Tools.—The variety of attachments now available for different standard machine tools enables the small-shop owner to acquire facilities quite readily for doing many things that in a production plant, or big tool room, would be handled on a machine designed more particularly for that class of operations. Milling attachments, high-speed spindles, slotting attachments, and others are used for doing a great variety of work on the one machine until it seems advisable to purchase a standard machine tool for doing such work.

In this connection it should be pointed out that so far as the toolroom is concerned, recent years have seen quite a number of new designs of equipment directed into the field of the diemaker and general toolmaker. As fast as his business warrants the outlay, the small-shop owner wisely acquires these newer and more effective tools and leaves his general-purpose machines available for the common run of work where special setups for difficult jobs are no longer necessary.

One factor in the costs of unusual jobs is found in the time required in handling them under the old methods which required constant rechecking for each detail of the work as it progressed through the machine. Older men are familiar with the almost universal practice in earlier days of boring all classes of jig and die work on the lathe faceplate, by the button method of locating the work for each successive hole. As work of this kind became larger and still required the same degree of accuracy as the smaller jobs, the difficulty of resetting and checking the work became such that eventually the milling machine was commonly employed for the purpose, and the precision horizontal boring machine was, and is, employed for larger work.

The jig-borer development for tools and dies generally has been one of the later great advances in machine-tool design. It is often used on the production of very accurate parts required in fairly large quantities, as well as for precision tool operations.

Selecting the Method.—However, the small shop will continue to do a good many tool-boring jobs on the lathe with remarkably accurate results from the button, sine bar, and similar methods in the hands of skilled workmen. Given equipment more particularly adapted to such purpose, the shop will often have the problem of determining how to handle a new job. Perhaps the best machine for the work cannot be used at once. Resort to

former methods may be necessary to save time in getting the work through the shop. Or, the job may be of so peculiar a character that it hardly falls within the conventional scope of any tool in the place. Special devices may have to be resorted to to accomplish satisfactory results. The experience with past performances will perhaps indicate the best approach to the undertaking.

An impatient customer not accustomed to the expense of rigging up special means for the work hardly appreciates the problem faced by the shop. And more than one controversy has been aroused after completion of a job as to the judgment displayed in fixing upon the method of procedure.

Degree of Accuracy.— There is another point that needs careful consideration, namely, accuracy. Customers do not always specify how accurate a job must be, and often they do not know to just what degree of accuracy the work should be held. This fact often causes argument over paying for a piece of work claimed to be unsatisfactory. The shop operator should settle such points before starting the work, and in doing so he will have to use rather rare qualities of judgment to satisfy the customer in advance and still be able to hold the job to the fine degree the man asks for. Some very unusual setups are necessary for much of this special work. Where sectional constructions are required by the design, there is always a chance for cumulative errors which may throw out the completed job and make it unsatisfactory. No man's experience is too broad to be brought to bear upon the best way to handle some of these projects.

The very method of starting an unusual piece of work may be the key to the result secured. This may be a case where there is really only one proper way to do the work, though often we expect any one of a half dozen ways should be entirely satisfactory.

In some cases it is advisable to make a wooden model of the piece to be made and paint the finished parts with aluminum or other finish. This makes it much easier for the tool designer to visualize the work to be done than he can do from drawings alone. It often results in developing holding methods and tooling that are much more efficient than would otherwise be produced.

Where there is doubt about the selection of the method, joint experience of several skilled men should fix upon the best of the

lot. The first operation so often determines the accuracy and the proper relation of most of the other operations. Only careful analysis can fix upon that first starting operation.

Many bore a hole and hang everything around that location. This may do for a jig plate or another flat piece, such as a die block. But with a long slender element, the hole location first provided may be the means of throwing out the opposite end of the job.

A SPECIALTY GRINDING PLANT

One of the best equipped plants for handling contract grinding in the West is the Coast Centerless Grinding Shop in Los Angeles. Primarily the plant is strictly a grinding and honing shop. But in addition to numerous grinding machines installed, there are naturally a number of allied machines available for special and service purposes.

The factory building 100 × 160 ft., with an office 30 × 60 ft. on the east end, has a total length along the front of 190 ft. Receiving and shipping facilities are in the immediate rear, and the entire shop area is left free for machining operations.

The equipment is conveniently grouped, and the lighting is evenly diffused from saw-tooth roof and side windows. There is good overhead clearance, free of belts and shafting, and there are no interfering factors around any of the machines. All machines are individually motorized.

All kinds of precision grinding and production grinding are handled on the basis of "Grinding jobs are delivered the same day as received." Equipment is here for all classes of grinding, including cylindrical and centerless work, internal and surface grinding, honing, etc.

Equipment.—The main features in the equipment are as follows:

Five Cincinnati centerless grinders.
Cincinnati 6 × 36 in. grinder, center type.
Norton 10 × 72 in., type C cylindrical grinder.
Norton 6 × 30 in., type C cylindrical grinder.
Four Landis cylindrical grinders.
Brown and Sharpe grinders.
Rivett precision bench grinder.
Two Blanchard surface grinders.

Thompson hydraulic surface grinder (9 × 41 in.).
Gallmeyer and Livingston surface grinders.
Heald surface grinder.

INTERNAL MACHINES

Six Heald No. 70 internal grinders.
Two Heald No. 72A Size-matics.
Heald No. 72A3 internal grinder.
Three Heald No. 80 internal grinders.
One Heald No. 60 internal grinder.

HONING MACHINES

Two Barnes Drill Company's honing machines, No. 306H and 194.

Besides the above there are floor grinders, cutter and tool grinders, bench equipment, and snagging grinders for hand-roughing-out operations preparatory to mechanical grinding, besides other tools adapted to the purposes of this plant.

This plant handles many classes of accurate work, particularly aircraft parts, as well as many other lines where exacting tolerances are maintained.

TURRET-LATHE USEFULNESS

Along with screw-machine considerations, it is of interest to consider the adaptability of the turret lathe in general. Built in different forms, the turret lathe is applied to about every type of work requiring turning, boring, facing, and similar operations carried on in the general shop as well as in large production plants. It is considered as useful for special short runs as for long repetitive undertakings. By a little reasonable planning in providing tools for such a machine, it can be adapted to many newer lines of work coming up from time to time. And due care paid to selection of turret tools, cross-slide equipment, and other tools will enable the user to apply the turret lathe to the general purpose of the average shop. By fitting up holders to carry the right kind of cutting tool, the jobs can be changed from one to another without much tool expense. Simple chucking is usually adequate for the purposes of short runs, and the setting of turret and cross-slide tools requires little time for the skilled user. Thus the machine becomes an important factor in handling

many types of jobs formerly considered solely as engine-lathe projects.

Shopmen are familiar with the fact that the automatic type of screw machine gradually becomes supplied with different cams suited to a variety of operations, and eventually these cams are adequate in number and type for almost every special job undertaken. The turret lathe is even more easily fitted up with about all the tools necessary for usual kinds of work, and this type of machine becomes more and more useful. For special long runs in volume of work, special tools are of great advantage. For the general lot of short jobs, simple cutting tools and chucking appliances will often answer every purpose. Turret-lathe builders now provide standardized tools that can be used on a wide variety of work.

WHEN NEW EQUIPMENT PAYS[1]

The two charts in Figs. 40 and 41 are used in surveying the economics of machine replacement at the Cleveland Automatic Machine Company.

Figure 40 is a form designed to facilitate the calculation of production increase to be expected from replacement of existing equipment by new machine tools. In use it is intended to "sample" production on the machine in question. Space is provided for a sample of ten representative items.

Assuming that a sample of ten items representative of the work can be selected and that it is agreed that the sample is truly representative, production and order records will yield all the information needed to fill in data required on present machines. While there are a number of indices of production available, such as seconds per piece, minutes per piece, pieces per hour, etc., "pieces per eight-hour day" has been used. The selection of this index should by no means be regarded as arbitrary; it was made because of the observation that operating men are more prone to trust this index and that it tends to eliminate "stunt" performances accompanied by a large amount of set-up time and time down for tool adjustment, sharpening, etc.

Proper weighting is given each item in the sample by taking account of the yearly requirements. This procedure avoids making large claims by spectacular savings on an item which perhaps does not bulk very large in the year's volume of production.

A word of explanation is needed concerning the presence of Columns *e* and *f* under the caption "Second Operation." In many cases machine

[1] By J. C. Wattleworth, vice-president, and G. V. Patrick, Eastern sales manager, The Cleveland Automatic Machine Company.

limitations have restricted the amount of work which may be done on existing machines, necessitating subsequent "second operations," either of a similar or dissimilar general nature to the first operation.

Where this limitation is either wholly or partly removed by a modern machine tool, so that "second operations" can be performed during the "first operation," the elimination or reduction of "second operations" can legitimately be claimed as a saving. This is accomplished in Fig. 40 by including such "second operations" as can be performed on new machines in the number of days for present machines.

Item	Yearly Volume	Present Machines					New Machines		
		1st Operation		2nd Operation (See Note Below)		Both			
		Pieces Per Day	Days Per Year	Pieces Per Day	Days Per Year	Days Per Year	Secs. Per Piece	Pieces Per Day @ 80%	Days Per Year
a	b	c	d	e	f	g	h	i	j
1.									
2									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
Totals									

NOTE In Columns e and f Post Only Separate Second Operations Which Are Included in Work of New Machines

Add Totals in Columns d and f and Post in Total in Column g.

$$\text{Production Increase, Percent} = \left[\frac{(\text{Col. } g \text{ total}) - (\text{Col. } j \text{ total})}{\text{Col. } g \text{ total}}\right] \times 100$$

NOTE: Day Referred to Is One Eight-Hour Shift.

FIG. 40.—Form to show production increase.

The performance of new machines is calculated, in this case in seconds per piece, and reduced to net piece per day (of eight hours) by taking 80 per cent of the gross production per day. The factor of 80 per cent above, used for reducing gross to net production, is, of course, subject to variation depending on individual cases; this should take into account the experience of the particular plant, the frequency of change over, improvements in facilities for set-up, and other factors which can not be allowed for in an average figure. The figure arrived at for net production is then converted into days per year for the same quantities shown in Column *b* and used previously.

As a result of the above, two figures are available; in Column *g* the number of days per year for the sample on present machines, including days spent in second operation; and in Column *j* the number of days

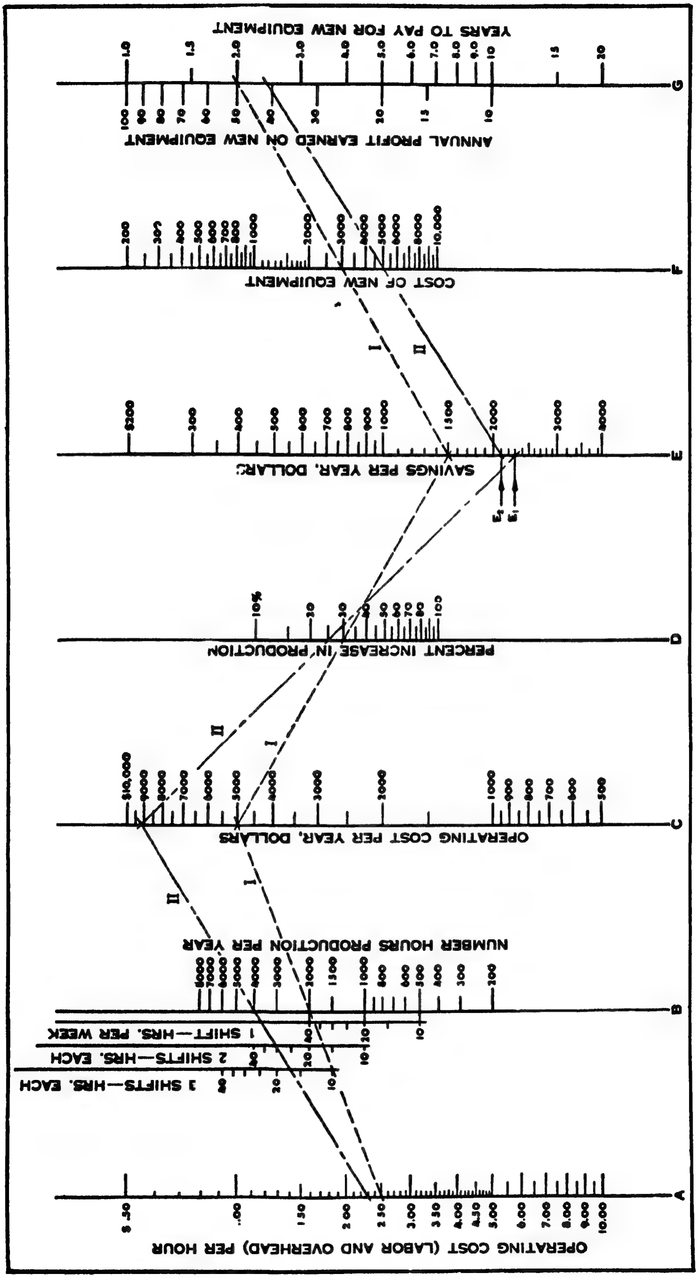

Fig. 41.—Chart for figuring investment return and profit.

Examples of Use of Fig. 41

Example 1—Old Equipment Fully Depreciated

Line *A*:	Operating cost	$2.50 per hour
Line *B*:	Operating one 40-hr. shift	2000 hr. yearly
Line *D*:	Production increase	30 per cent
Line *F*:	Cost of new equipment	$3000
Line *G*:	Solution (*a*) Equipment paid for	2 years
	(*b*) Annual profit on investment	50 per cent

Example 2—Incompletely Depreciated Equipment

Line *A*:	Operating cost		$2.30 per hour	
Line *B*:	Operating two 40-hr. shifts		4000 hr. yearly	
Line *D*:	Production increase		25 per cent	
Line *F*:	Proposal, new equipment		$4500	
	Plus undepreciated	$750		
	Less resale	250	500	
	Cost of replacement			$5000
Line *E*:	Gross saving per year (point E_1)		$2300	
	Depreciation of above at 10 per cent yearly	$500		
	Less previous depreciation charge	300		
	Increased depreciation		200	
	Net saving per year (point E_2)			$2100
Line *G*:	Solution (*a*) Equipment paid for		2.4 years	
	(*b*) Annual profit, absorbing undepreciated value of old equipment		42 per cent	
	(*c*) Actual profit, on new equipment only		51 per cent	

Instructions for Use with Fig. 41

Fully Depreciated Equipment

1. Determine the average operating cost in dollars (labor and overhead) per hour and locate on scale *A*.

2. Determine the normal hours per shift per week, and the number of shifts. Locate these in the appropriate column and transfer horizontally to scale *B*.

3. Draw a line through the points determined in (1) and (2) above, and prolong it to inter ect scale *C*. The intersection on scale *C* is the operating cost per year.

4. Determine the percentage increase in production by comparison of production rates on present equipment and based on proposal of new equipment; locate this value on scale *D*.

5. Draw a line through the point determined on scale *C* in (3) above and the point just located on scale *D*, and prolong this line to intersect scale *E*. The point of intersection on scale *E* is the saving in dollars per year made with the new equipment.

6. From proposal determine the cost of new equipment (including or excluding tools, depending on the policy of the individual company) and locate the value on scale *F*.

required on new machines, including second operations done on these machines simultaneously with the first operation.

The difference between these two numbers of days may then be interpreted as the saving on the given quantity, or as an increase of production available. Reduced to a percentage of the number of days required for the same quantity, this percentage is then ready for use in Fig. 41, the Investment Return or Profit Chart as "Per Cent Increase in Production," and entered on Scale *D*.

Figure 41 is largely self-explanatory. Production and cost records of course must be used to determine the information required for Scales *A* and *B*, and the figure needed for Scale *D* is obtained as described above. For the rest, the chart is an alignment chart with whose principles of solution most people are familiar.

PROVISION FOR NEW EQUIPMENT

We may have a $10,000 machine tool standing in our shop, and whether it is busy or not, it represents an investment whose

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7. The point of intersection on scale *G* of a line drawn through points determined on scales *E* and *F* gives the number of years required to pay for new equipment through saving only, and the annual percentage of profit earned on new equipment.

Incompletely Depreciated Equipment

1. Proceed with steps (1) to (5), inclusive, as explained above The intersection thus determined on scale *E* is the gross saving per year (point E_1 in Example 2).

2. To determine the net cost of new equipment, to the price of new equipment from proposal add the undepreciated value of old equipment and subtract resale or scrap value of old equipment. Locate this value on scale *F*.

3. Determine the depreciation charge of new equipment, based on the net cost in item 2 of this example. If the new depreciation rate is higher than the old, determine the net savings by subtracting from gross savings in item 1 of this example the difference between the new and old annual depreciation charges (point E_2 in Example 2).

4. Proceed from these values as previously explained in steps 7 and 8 for fully depreciated equipment.

5. The solution presents the situation during the time the net charge for old equipment is being depreciated through savings. After the depreciation charge is complete, actual profit is calculated as for "fully depreciated equipment."

NOTES: In cases where the undepreciated value of old equipment is too large to be reasonable and far in excess of the resale value, it is suggested that this amount should be a direct charge to the surplus account.

Normal depreciation is considered as 10 per cent annually.

In the above instructions no consideration has been given to savings made through reduced repair bills.

interest charges alone amount to about $600 per year, or about $2 per working day.[1] Owing to the fact that tools change so rapidly in design as a result in changes in manufacturing necessities, an annual charge based upon a 10-year period for establishing a fund for buying a newer tool amounts to another $1000 or more. So here is another $3 per day to be earned throughout the life of this particular machine if its purchase is to be looked upon as "self-liquidating."

The use of a 10-year term in computing the rate of depreciation or the reaching of the period of obsolescence is merely an arbitrary matter. Under some circumstances, such as in a production shop, the machine should probably be replaced in a shorter period of time. On the other hand the tool may justify continued use after the 10 years mentioned. If, however, we are dealing with advance production practices, we shall have to change to later designs sooner than once in 10 years for many types of machines. Although the machine may be in good condition, it will, just the same, become expensive to retain it too long under modern competitive conditions. The newer models make possible the use of faster speeds, heavier cuts and rates of feed, and general increase of production with, too, usually a better finished product.

Special Equipment.—The features of increased speed, heavier cuts and rates of feed, and increased production are emphasized particularly with automatic and semi-automatic equipment developed for specialty manufacture. Also certain types of machines built for toolroom purposes show the wide advances over earlier models. The growing use of highly developed jigs and fixtures and increased use of larger and more intricate dies for heavy presswork have been accompanied by the construction of specialized tools for aiding in the building of such fixtures and power-press appurtenances. Where these are installed they have absorbed much of the work formerly handled on the common types of tools generally found in the toolroom.

When a shop executive is considering possible expenses over some given period, he must take into consideration this factor of continued improvement in most types of shop tools and form some estimate regarding just what this condition means to him

[1] Based on 6 per cent interest. It is probable that a lower rate, perhaps 3 or 4 per cent, will be more common in future.

and his plant. Investment charges for tools already installed are, of course, known amounts, and overhead expenses are determinable with reasonable accuracy. Materials and labor charges are figured as part of the day's business. All these elements must be carefully studied when laying plans for the future; any plans looking toward further expansion must include provision for wiping out the costs of present equipment within reasonable periods and providing means for purchasing newer and better machines.

OBSOLESCENCE

Years ago no one ever wanted to see a drill press or a lathe discarded, and no one ever expected to see a machine really worn out past all service. Today, by way of contrast, many new tools are expected to pay for themselves in a relatively short time and soon after to make way for something even better in the way of equipment. After a few years the factor of obsolescence appears and we can no longer afford to use a machine which, although still in good condition, cannot keep pace with something newer and more efficient in its operations. This is saying nothing against the discarded machine but merely drawing attention to the fact that tool design and construction improves continuously, and, relatively speaking, earlier constructions fall out as real competitors in producing lines.

Progress in tool design keeps up with the advances in steel-making and with progress in other industrial branches which look forward to the demands of tomorrow. Progress in the materials of which cutting tools are made and in the materials which such tools must machine makes obligatory rapid advances in the design and construction of the modern shop-production machine, as well as the equipment of the progressive toolroom.

It should be remembered that many jobs now handled in the toolroom are of such character that rapid cuts and removal of material are necessary if money is to be made on contract prices. The light, slow cuts of a former time have gone by. High-speed spindles are doing more work in a very much shorter time than was possible with some of the toolroom machines we formerly used.

In all discussion regarding the factors of obsolescence it should be kept in kind that one of the strongest arguments for better

and better toolroom and factory equipment lies in the constantly growing demand for a higher quality of product from these tools. This gage of quality is becoming more and more advanced. Formerly when shafting was turned to a ring gage, it was good enough; but that method was superseded by grinding. Even with the grinding process refined as it is, there are many jobs where the work is so exacting that only the finest class of grinding is acceptable. On gage and tool work the process of lapping carries refinement still further, and honing and superfinish impart to production jobs a character of surface and a degree of accuracy way past any dream the earlier mechanics may have had.

MISCELLANEOUS SHOP EQUIPMENT

Receptacles for Small Parts.—Miscellaneous small parts have a way of collecting about the work bench, either loose or unassorted in cans, and much time is lost in sorting them over to find the part wanted. Figure 42 shows a neat and simple way to take care of such parts.

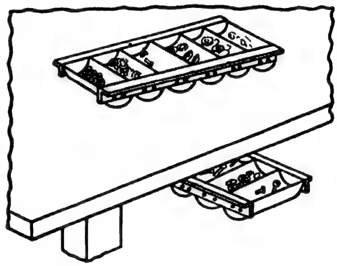


Fig. 42 Small round cans slit lengthwise, opened out, and riveted to pieces of light angle iron make convenient trays, or drawers, for small parts.

Small round cans, all of one size and with the covers attached, are slit lengthwise on one side and through the ends, opened out and made into nests by riveting the ends to pieces of light-weight angle iron. The nests can then be used either as bench trays or drawers as indicated in the sketch.

Storage Rack for Short Drill Rods.- Wastage of drill rods due to handling and marring by contact with other material led to the design of the rack shown in Fig. 43. The method of storing permits the short lengths to be placed in front where they can easily be seen and fished out. It also keeps the different sizes in plain view and the pieces wanted for use are the only ones that need to be handled.

The height of the rack is considerably less than is usual, making it practicable to place it higher from the floor. The lower edges of the front crossbars are at even inches from the bottom of the shelf on which the rods stand, making it easy to judge the approxi-

mate length of short rods. The partitions can be spaced to suit requirements of stock of various sizes as conditions may demand. Rods of two sizes can be placed in the same compartment without causing confusion, providing they vary enough in size so that one would not be mistaken from the other. A compartment for short pieces laid horizontally is provided under each vertical compartment.

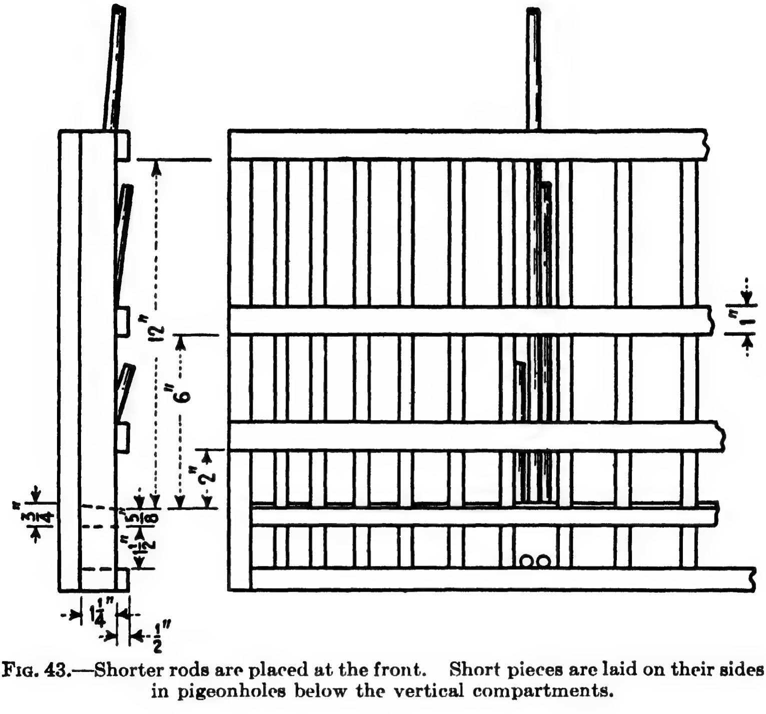


FIG. 43.—Shorter rods are placed at the front. Short pieces are laid on their sides in pigeonholes below the vertical compartments.

The side view shows how rods of short and medium length project outward slightly beyond the face of the rack where they can easily be seen, encouraging the use of as short lengths as will answer for the job in hand. The rack provides for all pieces however short they may be, and most of them will be used to advantage sooner or later.

Rack for Flat Tool-steel Stock.—Many users of ground, flat, tool-steel stock keep it loosely in a box under the bench. Every time they want a piece of a certain thickness, they have to handle

and "mike" nearly all of it before finding a piece suitable for the particular job in hand.

To obviate that condition and to have the stock conveniently at hand, the rack illustrated in Fig. 44 was built. It was made from 20-gage black iron and has sixteen compartments, each 4 × 4 × 18 in. The partitions have a lap of ¼ in. and are held in place by ⅛-in. round-head stove bolts. Or the rack can all be spot-welded. Tabs made from the same material as that of the rack are attached to the top of each compartment and are stamped with the thickness of the material stored therein.

The rack can be stood on or under the bench, or it can be mounted on a stand as shown. The stand is made of ⅛ × 1 in. angle iron with stiffeners of flat iron and is fastened to the floor with wood screws. With such a rack, stock of the thickness required can always be found quickly.

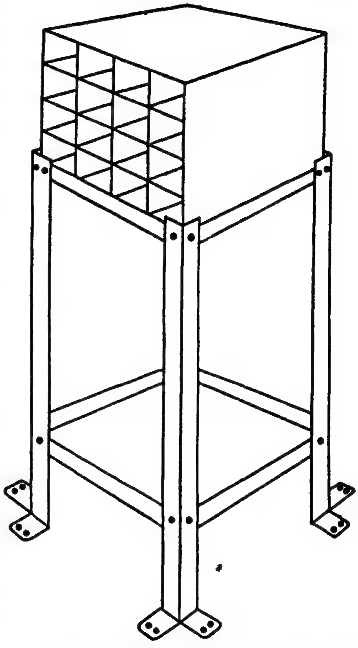


FIG. 44.—The rack is made from 20-gage black iron and has 16 compartments, each 4 × 4 × 18 in., for storing ground, flat, tool-steel stock.

Storing Short Lengths of Stock.—Every shop is confronted with the problem of keeping short lengths of bar stock where they can be found. If they are thrown into a box or a pile, much time is lost in hunting for piece of the right size for the job in hand. If it is not found the time spent in hunting is a total loss.

One small shop solved this problem by the method shown in Fig. 45. They mounted the power hack saw on a foundation high enough to bring the stock which is being cut at a convenient bench height. This bench helps in handling long bars of stock into and out of the machine. When short pieces are left from the bars, they are placed in the cabinet or rack shown partially beside the hack saw. Here all the short pieces are easily seen,

and a man knows at once whether there is a piece in stock that will answer his purpose.

Punch and Die Storage.—The problem of keeping punches and dies where they will be readily accessible and at the same time out of the way of dirt and chips was solved by one Texas shop as shown in Fig. 46. The shelves or bins shown are built against the wall directly behind the punch press for convenience

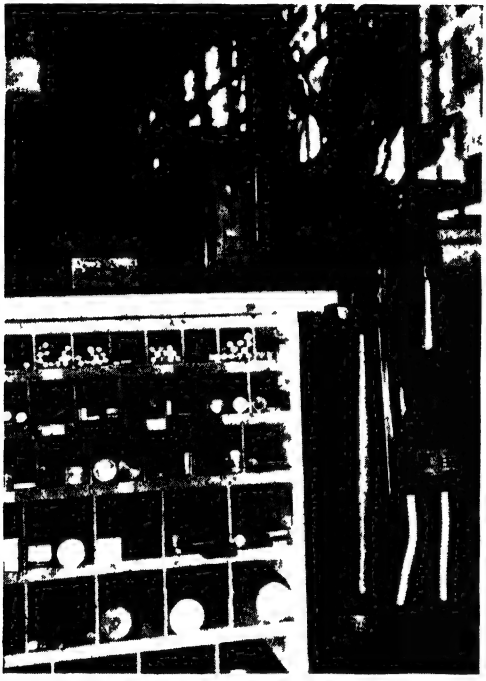


Fig. 45—Storage bins for short pieces beside a power hack saw.

in handling. Each bin has a cover which hinges at the bottom and drops down out of the way when tools are being taken or put back. When closed, they are held by a small catch at the top and keep the tools clean.

Each bin cover is plainly numbered so that it is easy to find any tool wanted without delay. The rolling ladder in front of the bins makes its easy to get at any particular one that may be wanted.

Timesaving Tool Trucks.—Much time is lost in many shops by not having the right wrench or other tool available at the

machine being repaired or other work being done. The old joke about the plumber always going back to his shop for tools has many counterparts.

The truck shown in Fig. 47 is one of several in the shops of the Churchill Weavers, Berea, Ky. Whenever a job is to be done, the tool truck goes along. As will be seen this carries a very

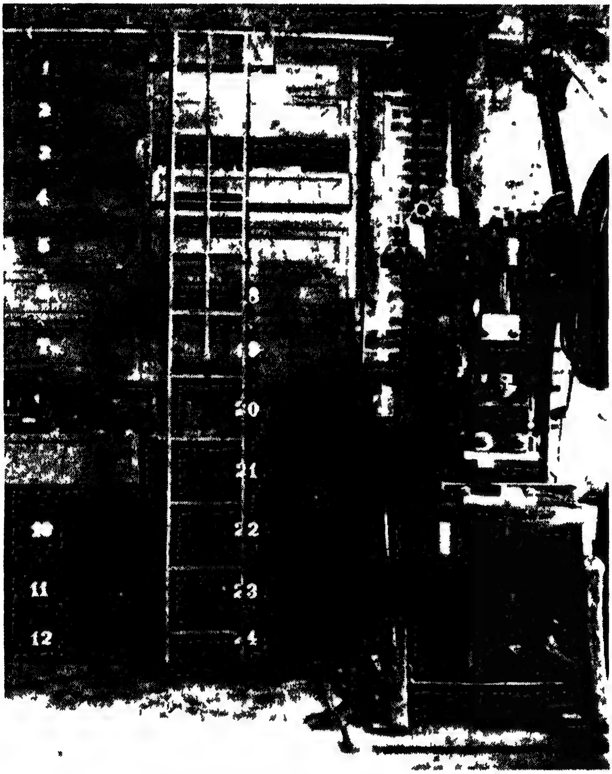


FIG. 46 —Shelves for tools behind a punch press.

complete line of wrenches. The three black outlines on the end show that the wrenches belonging on those pegs are missing. The socket wrenches on the side with screw-driver handles are most convenient in some cases. At the top is a very complete set of loose sockets with suitable handles.

The wrench-supporting pyramid turns on the triangular base which has large, rubber-tired, swiveling casters that make it easy to move it anywhere in the shop.

Shop Desks.—There are many places where shop desks can be used to advantage, such as by subforeman, timekeepers, and others. The desk shown in Fig. 48 is easy to make, costs little, and is well liked by the men.

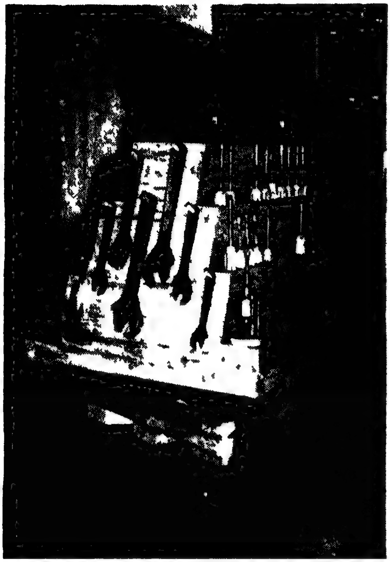


Fig 47.—Repairman's tool truck

It is 32 in. square, 45 in. high in front, and 48 in. at the back. The framework is made of $1\frac{1}{4}$-in. angle iron welded together. The desk proper is made of $\frac{3}{4}$-in. pine and fits into the four corners formed by the angle-iron legs and is supported by the upper crosspieces. If the wooden part becomes marred too badly it can be removed and replaced at a small cost. The sloping part of the top is hinged so that it can be lifted up and papers, etc., can be put in the body. A sheet of cardboard or heavy paper pinned to the sloping top with thumb tacks makes a good writing pad.

Shop Lighting.—Proper artificial lighting is a problem for those who have studied the subject carefully. It no longer depends on what "seems" to be right, the amount of light is now measured at the point where it is needed. This may be either at the machine or at the inspection or assembly bench.

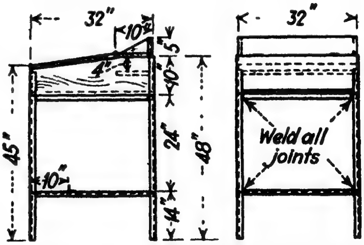


Fig. 48.—A shop desk of this type will stand much hard use, and when the wooden part is damaged, it can be replaced at small cost.

The kind of light is also important. Too intense light is not as good as a diffused light in most places. This is shown in Figs. 49 and 50. In Fig. 49 the light on the hands and micrometer is about as strong as that in Fig. 50. But the diffusion of the light in Fig. 50 is not only easier on the eyes, it makes the graduations and figures on the micrometer more readable and

helps to prevent errors. A lighting expert can make suggestions that will be helpful in many ways.

CUTTING LUBRICANTS IN THE MACHINE SHOP

The use of satisfactory lubricants and coolants applied in such floods as to be of real service on production jobs is a feature of the

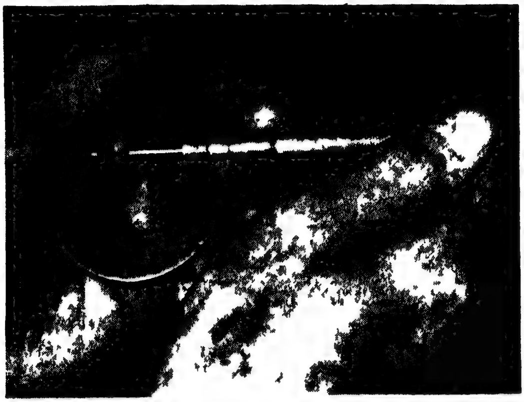


Fig 49 —Poor lighting leads to errors

Fig. 50.—Uniform lighting makes it easier to read the micrometer.

modern manufacturing system. It developed as a necessity of and aid to rapid metalworking processes. Particularly is this true of the application of cutting fluids to high-speed drilling operations, turret lathe and automatic screw-machine work, general milling-machine jobs, and many other classes of work handled in lathes and other machine tools. Originally only the

simplest means were provided for supplying the cutting liquids of the times to the tool and work. Today, on many jobs the flood of lubricant is second only in importance to the cutting tools themselves.

Proper kinds of cutting lubricants effect many results, which vary in character. On work where they are applied to the fullest advantage, they permit faster cutting speeds and coarser rates of feeds. Properly cooled work and tools result in longer life of the tool between sharpenings and in longer ultimate life of the tool with respect to its cutting edge. Reduction in horsepower for driving cuts under high speeds and rapid feed rates is brought about by suitable cutting fluids directed immediately to the point of application of the tool to the work. This is especially noticeable in the running of heavy cuts on milling machines where a cut of considerable length is possible and checking of speed and feed rates easily attended to. The means for supplying the cutting lubricant to milling cutter and work are ideal in such cases and provide ample opportunity to compare power requirements for work machined under a copious flow of fluid with similar work performed either under dry conditions or with improperly applied cutting lubricants.

Flooded Lubrication.— Necessarily, the effect of flooded lubrication of cutters and work surface is, among other things mentioned, to produce a smoother surface on the job and in general cause more accurate and better results throughout. One of the early troubles encountered with all classes of machine operations when undertaken at an increased rate of speed was the tendency toward production of roughness in the machined surface and inaccuracies of one kind or another. These troubles were due mainly to the fact that an increased volume of heat accompanied the speeding up of operations without any adequate method of carrying away that heat before it became troublesome.

In the case of a milling job where considerable surface was being finished under the cutter, the heat under the early conditions referred to would cause some slight change in the work surface due to its expansion. Consequently, the cutter in following along its path would face off these "high" spots and the result would sometimes be a concave surface of considerable degree of curvature.

Similar results have sometimes been discovered in certain classes of surface grinding where, for example, heat was ineffectually dissipated and where as an outcome the work would "buckle" slightly; the wheel in passing would then cut away that elevated portion, showing in the final test anything but a plane surface.

Distortion, particularly localized distortion, has been the cause of many spoiled jobs that otherwise would have been eminently satisfactory. And back of this distortion lay the simple explanation of inadequate lubrication and cooling of work and tools.

At the time the milling machine emerged from the toolroom as a means of fluting drills, reamers, and taps and began to be used for heavier manufacturing cuts than were required in arsenal and sewing-machine operations, it still made use of fine, closely spaced tooth cutters which were adapted for relatively light cuts. The teeth were soon clogged with chips or fine iron or steel particles and drip-cup lubrication was hardly sufficient to wash out the cutter teeth or cool the work surface. Application of special coolant pumps for flooding the job and increase in the coarseness of cutter teeth were accompanying improvements that gave marked impetus to the use of the process of milling in the machine shop and manufacturing plant.

Selecting Lubricants.—Cutting lubricants vary widely in character, their general selection being based upon both the kind of metal being machined and the particular class of operation being performed on that material. Again, there is a range of choice depending upon the type of machine that is used for the job; that is, in considering three ways of cutting threads, in, say, bolt cutters or threading machines (with dies), the engine lathe (with single point tool), or the thread miller (with the use of a milling cutter), there would very likely be three distinct recommendations by lubricant engineers as to suitable cutting fluids for the three classes of operations.

These lubricating materials range from so-called "soda" water and clear-water kerosene and lard oil to water emulsions and other special compounds. On steels of various kinds these cutting coolants may vary all the way from fairly light fluids to such mixtures as white lead with lard oil.

Aside from bolt cutters and turret lathes, very few of the earlier shop machines were equipped for anything like adequate supplies of cutting lubricants. The drip cup referred to above was usually found on the lathe (when turning shafting) and on the milling machine as then employed. So far as drilling operations were concerned, the simple oilcan usually served every purpose.

Without doubt, these limited facilities for cooling both work and cutting tools played a large part in holding back the earlier adoption of rapid speeds and feeds on practically all classes of machine tools. Certain classes of plants, however, had gone a long way at the time in applying lubrication under the most effective conditions for some special types of work. For illustration note the use of the oil-tube drill in the gun-barrel driller with forced lubrications to the very point of the drill. Also note the use of forced lubrication for drilling and forming bicycle hubs simultaneously on a special type of semi-automatic turret lathe. The cartridge manufacturers too had long since adopted thorough lubrication for their metal cups and shells as drawn out in successive processes from a simple disk to the elongated form which, when finally headed and primed, was ready for reception of the powder charge and bullet. No less than six or seven draws were required for many of the metal cases manufactured, and in each drawing operation the shells came from their supply tubs immersed in soap suds and ready to run through the dies without a sign of scratch or blemish.

Whatever the class of work under consideration, one essential for high-speed, smooth operations is the use of plenty of cutting lubricant applied at the right place—and sometimes that means all over the exposed surface. All operations except roughing ones are performed with the attempt to keep the work surface as cool as feasible. To that end various types of cooling mediums have been developed by different manufacturers and these all have their very useful fields. Each type has its advocates, and preference is not always based on logical reasons.

In fine grinding operations it has been found that better work and longer wheel life has resulted from filtering and cleaning the cutting liquids. Centrifugal separators, similar to those used in dairies, are now used very successfully for this work. They take out the particles of metal, abrasives, and bond and give better results in every way.

Effect of Cutting Oils on Men

Skin troubles of men in the shop are sometimes attributed to the cutting oils and compounds used, according to J. T. Beard, mechanical engineer of the Socony-Vacuum Oil Company.

Cutting and soluble oils, shipped from the various refiners, contain no harmful bacteria. The heat of the manufacturing and blending processes has killed all such organisms if they ever existed. Nevertheless, operators of machine tools are sometimes afflicted with pimples, boils or rashes from the use of these products. This is caused by the penetrating property that should be possessed by all good lubricants and coolants —a property which enables them to enter the pores of the skin.

This entrance of the cutting oil into the skin would be harmless, providing the oil carried no harmful material with it. The skin itself, however, is literally covered with harmful bacteria. Recently the Life Extension Institute has stated that 27 distinct diseases can be communicated by the bacteria on the skin of the average person.

Skin infections can be prevented by personal cleanliness and by strict plant hygiene. The following general rules are considered fundamental:

1. Keep drums and tanks covered, thus excluding dirt and germs.
2. Keep the skin of the body clean.
3. Protect the hands and arms from infection by rubbing vaseline, lanoline, or other ointment into the skin before starting work.
4. Change from street clothes to shop clothes before starting the shift.
5. Thoroughly wash hands and arms with soap and hot water after stopping work.
6. Use individual towels and brushes.
7. Avoid the use of waste or rags for cleansing the skin.
8. Change from work clothes to street clothes before going home.
9. Thoroughly wash or launder working clothes at least once a week.
10. Change underwear at least once a week.
11. Don't spit into drains and oil pans.
12. Attend promptly to cuts, abrasions, and skin rashes.

CHAPTER 4

SHOP TRANSPORT AND MATERIALS HANDLING

Shop transport includes everything from moving or handling raw material of any kind to the delivery of the finished product at the shipping platform. It also includes the handling of the tools used and of the commercial parts that go into the products while the work is in process. Even in small shops this frequently consumes a larger proportion of the total cost than is always realized.

Some consider it better to make two separate operations of handling materials at the machine and moving materials from one place to another. They prefer the term "materials handling" for the latter operation. It matters little, however, just how we divide the operations so long as we do not overlook the various costs or the equipment necessary for economical performance. We have learned that it is cheaper to provide mechanical equipment than to tire men unduly by lifting or moving heavy work.

Appliances.– Materials- and work-handling appliances vary widely, depending on both the weight and the bulk of the pieces and on the quantity. Small hand hoists, usually with chains, air hoists of either the air-motor or the straight-lift variety, which were formerly much more common than now, electric-motor hoists, and traveling cranes of various types all have their place. There are also many places where the jib type of crane, equipped with either a hand or power hoist, gives excellent satisfaction at comparatively low costs. Some of the newer shops are making provision for the installation of jib cranes on any post or column by casting iron pipe in the columns at regular intervals so that bolts can be put through at any time. This allows the changing of plans quite readily, should shop conditions vary materially from the original plans.

In considering the cost of installing and operating hoists, cranes, or other materials-handling devices, the cost of *not*

having them in sufficient quantity must also be borne in mind. When workmen must wait for crane or hoist service, it means nonproductive time for them and usually for their machine.

MATERIALS STORAGE

In their way, sources of supply and the availability of materials are as important in a small shop as in a large one. With bar stock, screws, bolts, and nuts available from a local supply house and castings from a nearby foundry it is only necessary to store material for current needs. But whatever the storage space, the chief requirement is that the material wanted should be easily found and easily removed from the racks or bins.

Racks and Bins.—Commercial storage bins and racks are now available that usually make it inadvisable to build them in the shop. Most of these are of metal, which is not only more durable than wood but also greatly reduces the fire hazard. And fire hazard in shops is greater than it might seem with so much of the equipment made of metal. A visit to any shop after a fire will show more damage than one would think possible in view of the amount of metal used.

Where bins are used, one of the first considerations is that the material be visible and accessible. The ease with which they can be cleaned is also important. Unless materials are visible and accessible, work may frequently be delayed by waiting for material that is already on hand but was overlooked in checking.

Racks for bar stock are now made commercially to suit nearly all requirements. Strength is a major consideration, as bar stock is heavy and a collapse might endanger life and limb. Adaptability to material of different kinds and holding short pieces are also considerations. Location of bins, drawers, and racks in the shop is often something of a problem. It is seldom possible or advisable to place them near windows without darkening the rest of the shop or using daylight that is needed for the machines. In most cases, however, artificial lighting is better for storage spaces, for it can be directed just where it is needed. Plenty of light should be provided. Both general lighting and individual portable lamps, which can illuminate the interior of any bin, will be found to be a paying investment. With convenient switches for turning lights off when not in use and a little intensive training to see that this is done, ample

illumination will prove to be one of the best investments in any part of the shop.

Locating the racks in which long bars or screw-machine stock is stored is sometimes quite a problem. With the racks backed against the wall, as is common, it is necessary to leave a very wide aisle to provide room for withdrawing the bars when wanted. One solution for this problem is to put the racks at an angle so that the bars lie at an angle to the wall and aisle, just as screw machines are frequently located, so that the long bar from one laps by the next machine. This method has proved very successful in one fairly large plant, saving considerable floor space in aisle width and proving very satisfactory in every way.

Storage Methods.—In some instances the storing of small parts, such as pins, rivets, and screws, may be more troublesome than storing larger parts. Unless they are used in much larger quantities than in the average shop, it is usually better to keep them in comparatively small receptacles that are readily accessible and can be easily examined. For this reason, many prefer the use of small glass jars for holding screws and the like, for the contents can be readily seen and counted, if necessary or desirable. With these jars stored on shelves in plain view, one can see almost at a glance just what small parts are available and how many. Most users of this method keep them on shelves of suitable dimensions in the regular way. Some, however, prefer to fasten the covers of the jars to the under side of the shelf. The jar is unscrewed to get at the contents and screwed back in place when no longer needed. One advantage of this method is that the jars are securely held at all times and no jarring causes them to work off the shelves and fall to the floor. The plan seems better adapted to a single row of jars, as along the back of a bench, than for storage racks with a number of rows of shelves. For unless there is ample room for the hand beneath the jars to unscrew them, much time will be lost in getting at the jars, and more space is required than for shelves used in the regular way.

Storage of sheet metals of various kinds presents its own problem. Some prefer to keep it flat on shelves while others consider it more convenient to have sheets on edge so that any special sheet can be removed without disturbing the others. The main thing is to keep the sheets of the same thickness and of the same

materials together. With very thin sheets it is almost necessary to store them flat in order to prevent buckling and other damage.

As with all materials, one of the main problems is to keep the small pieces, odds and ends, where they can be readily seen. As with scrap of all kinds, its main asset is in having it available when needed. In too many cases more time is wasted in hunting through the scrap pile than the salvaged material is worth. Unless scrap can be so segregated that its contents are easily accessible, it is more likely to be a liability than an asset. Hours wasted hunting through a pile of scrap for a piece that you thought was there would frequently buy new material and with far less strain on the disposition. If it does not seem feasible to keep scrap material sorted so that desired pieces can be readily found, it is usually cheaper and better to send it to the junkman than to have it around the shop.

HANDLING WORK IN THE SHOP

There are many methods of handling work, from trucking it to the machines either in units or in boxes to the continuous conveyor that brings the work to, and sometimes through, the machine that is to do the work. Gravity conveyors, consisting of rollers supported in a frame at a slight incline, are very common. The work, either in units or in boxes, is placed on the conveyor at a high point, and it feeds down by gravity to the machines. After an operation is completed, the work is put back on the same, or another, conveyor and passes to another machine. In some cases the gravity conveyor is simply a link between conveyors of other types.

Conveyors for Heavy Work.– In Fig. 51 is a typical conveyor for fairly heavy work, a Ford cylinder block in this case. Small platforms or trucks are pulled along runways by a chain or cable. This shows an 8-cylinder block at the left, then an empty platform to show its construction, and a 4-cylinder block at the right. The block in the center is leaving the machine line on the overhead conveyor, being headed for the assembly line. The clamps are suspended from the overhead conveyor chain, the conveyor going up an incline that will clear the blocks on the conveyors at the right. The overhead conveyor also carries flywheels and other parts needed at the engine assembly line. For short movements plain steel rails are frequently used as in

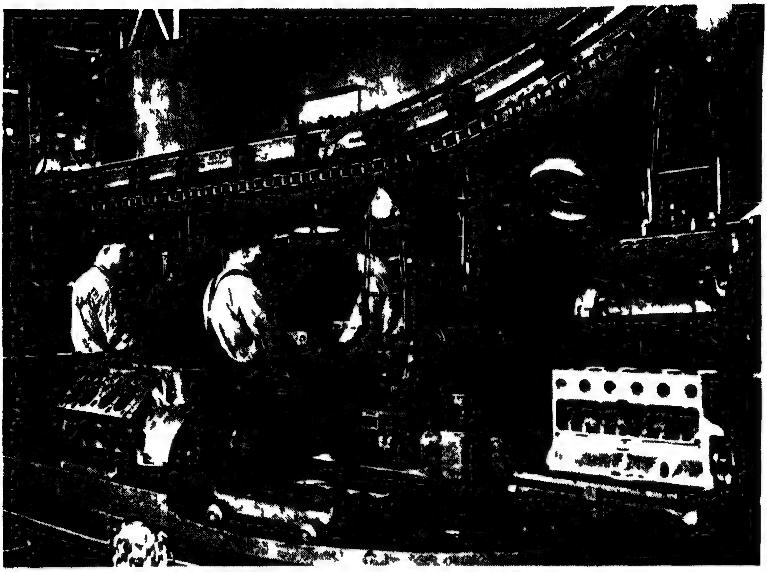


FIG. 51.—A good example of a conveyor line.

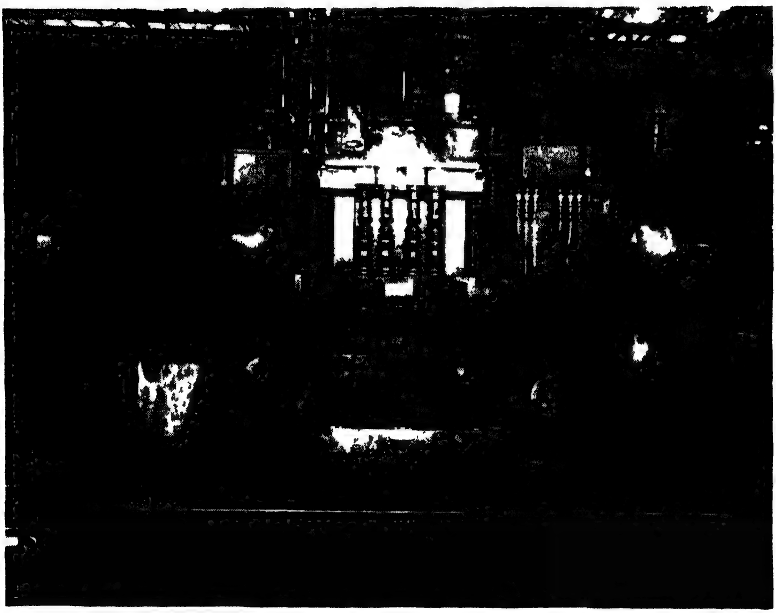


FIG. 52.—Rails used as platform for moving work.

the front in Fig. 52. When the operation is completed, the cylinder block will be lifted to the rails and pushed to the next machine. In Fig. 53 is one type of conveyor where the work goes directly through the machine. The double-chain conveyor picks up the cylinder block from the plain table in front and carries it into the machine. In most cases of this kind the work is fed against a stop and then raised from the conveyor, which continues its movement. When the operation is finished, the

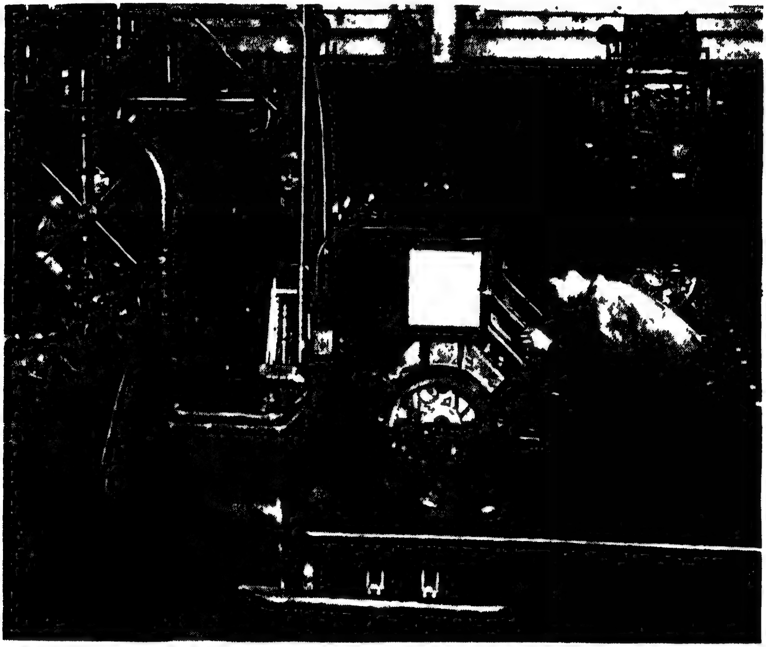


Fig. 53.—Chain conveyor feeds work into machine.

work drops back on the conveyors and is carried to the next machine. Raising the work from the conveyor permits it to be located correctly and clamped without interfering with the work of the conveyor at other machines. In some instances it is more convenient to have the conveyor run intermittently, stopping while the operation is being performed. The conveyor can be controlled by hand or by any of the machines in the production line. In most cases the operations are so timed that the work moves at regular intervals.

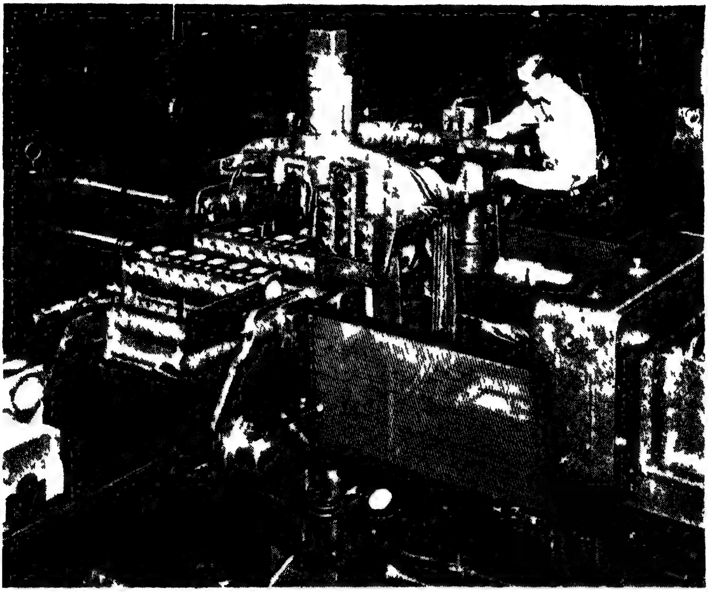


Fig 54 —Conveyors carry work from one machine to the next

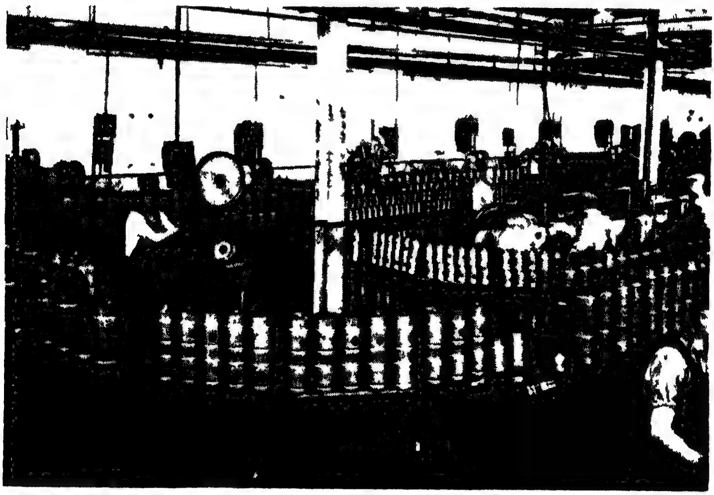


Fig 55.—How conveyors conserve space.

Other Types of Conveyors.—Conveyors have come to play a very important part in nearly all machine-shop work. They are used for both light and heavy materials and are not necessarily confined to huge quantities of the same piece. In one plant, for example, a long conveyor brings castings from the foundry to the machine shop and through the entire machining line. Other conveyors bring parts and subassemblies to the main assembly conveyor, where final assembly is made with the conveyor in

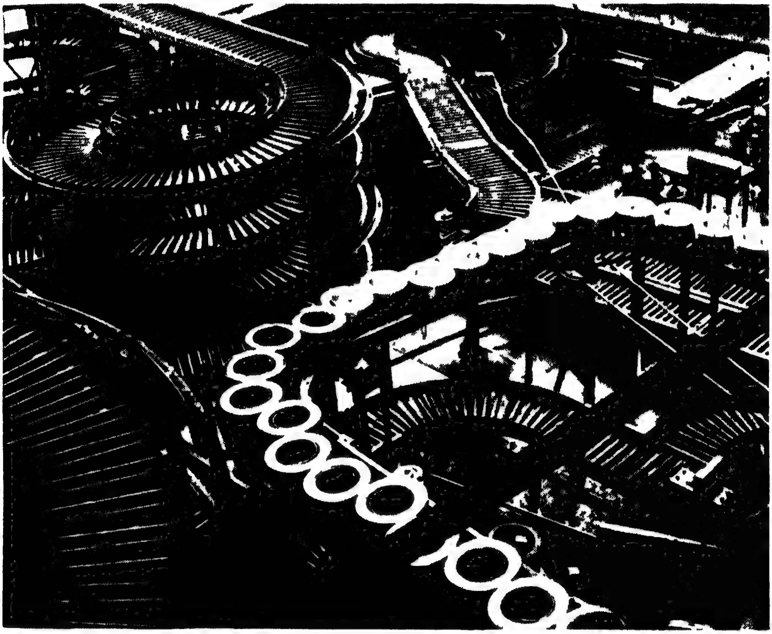


FIG. 56.—An excellent example of a gravity conveyor.

motion. The conveyor takes the finished motor through the test department, where it is checked and run, still on the conveyor. Then it goes through the paint-spray booth and drying oven and to the boxing department where the box is built to enclose the motor. From here it goes to storage or direct to the freight car that carries it to its destination.

In contrast to this, the same plant has a huge conveyor on which another type of machine is assembled in all its various sizes. This is, of course, a very slow moving conveyor which permits both large and small motors to be assembled on adjoining sections.

An example of the way in which a conveyor feeds work to a machine and after the operation is done takes it to the next is seen in Fig. 54. Holes are drilled and bored from each end of the cylinder block, and after this is done, the block goes on the roller conveyor to the next machine. This is not a power-driven conveyor.

Fig. 57.—Simple conveyor rails without power.

Other examples of roller conveyors, some with enough incline to let the work roll of its own weight, are seen in Figs. 55 and 56. Figure 55 shows a piston department of a truck-engine shop where the work is stacked on metal plates that roll along the track, either by hand or by gravity. A very complicated gravity conveyor for rolls of sheet metals in the plant of the Revere Copper and Brass Co. is seen in Fig. 56. This is perhaps one of the most compact installations in the country.

A very different type of conveyor, from the Caterpillar Tractor plant, is shown in Fig. 57. This is for a subassembly of the steering-clutch group and is of rather unusual construction. The arrangement of the structural shapes on the left track is worth studying. This makes slots for the sprocket and a collar to the left of it and acts as a positive guide for the unit as it is rolled

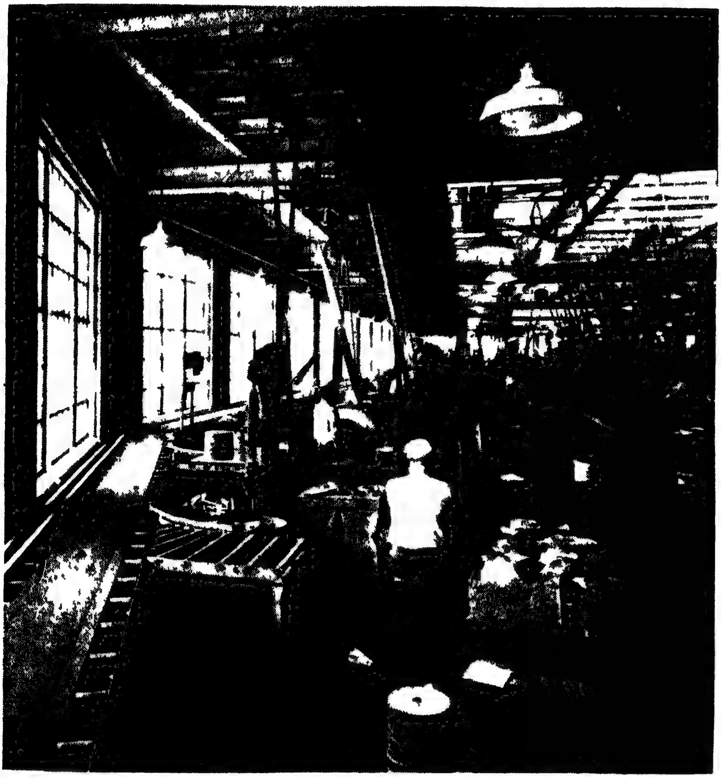


Fig. 58 —Belt conveyor with "feed-in" stations.

from one position to the next. The pneumatic hoist over this end of the track lifts it off when completed.

A combination belt and roller conveyor in the plant of the Norton Co. is shown in Fig. 58. Here a belt runs over supporting rollers. It is unusual to find a conveyor running along the wall as it does in this case. The conveyor is divided at the bend shown, the work being carried on by another belt that also follows the wall at the new angle. Here too is a lead-in switch

on which work can be placed before it is fed on to the conveying belt.

Another motor subassembly is seen in Fig. 59. Here the conveyor is of the jointed-board type, flush with the floor, and has assembly stands bolted to the platform units. This arrangement is notable for its wide aisles, for the stock storage bins for the parts needed in assembly, and for the convenience of having

FIG. 59.—Wide aisle, work stands, and tools suspended overhead.

the tools suspended over the men, ready for use but out of the way at all times.

Three types of motor-assembly conveyors are shown in Figs. 60, 61, and 62. Figure 60 also shows the board type of conveyor, but it is raised so as to bring the work at convenient height for the men. Here too the drills and all portable tools are suspended overhead, as in Fig. 59.

In Fig. 61 the work platforms are of metal, and each is provided with a turntable so that the worker can get at either side or end by merely turning the table on the ball bearings. Between each

table is a metal pan for holding small parts, such as nuts and pins that are used in assembly.

Still another type of conveyor is shown in Fig. 62. This is also for motor assembly. Here there is an overhead conveyor with the trolley wheels running on the flanges of the I beam. Two of these wheels support a frame that holds the motor and is

Fig. 60.—Continuous workbench in a motor plant.

guided in a slot in the floor by an extension of the frame proper. This frame carries a motor support that is pivoted so as to permit the motor to be tilted into any position for getting at various parts. An empty frame is seen returning on the line behind.

Conveyors in the Inspection Department.—The Waukesha Motor Co. found it advisable and economical to introduce conveyors into their inspection department, and some of the advantages are described by their general shop superintendent A. A.

Herzberg. These were installed because it was felt that incoming material should be put in motion as soon as it arrived on the receiving floor. With inspection at this point and purchases properly arranged, inventory of incoming parts can be kept at a minimum.

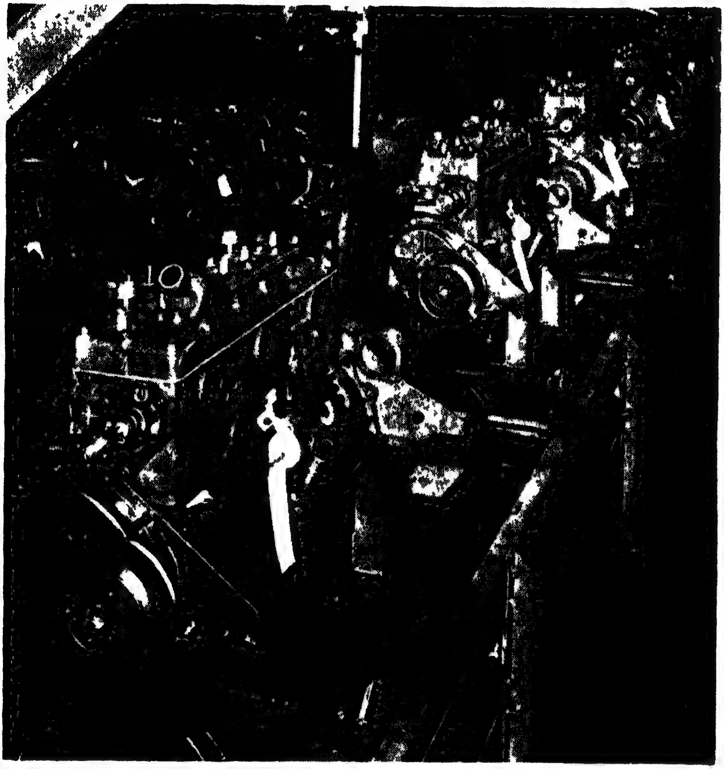


FIG. 61.—Continuously moving power conveyor for assembling motors Turntables permit rotating to any desired position

The receiving space is comparatively limited, as will be seen in Fig. 63. Parts are uncrated in the receiving department and those that are to be inspected are placed on the roller conveyor near the wall. Those parts which are not inspected are placed on the other conveyor and moved directly to the stock rooms or the assembly line. Material which has been placed on the conveyor for inspection is moved down the line to sections of cross conveyors. The parts are inspected by men stationed at benches in front of the cross conveyors. Parts are then passed on to the

conveyor which moves directly to the stockrooms or assembly line.

An indication of the type of inspection handled here can be gained from the following list of parts, for many of which special gages are arranged on the benches: pistons, push rods, cap screws, valves, oil pumps, water pumps, bearings, bushings, and gaskets.

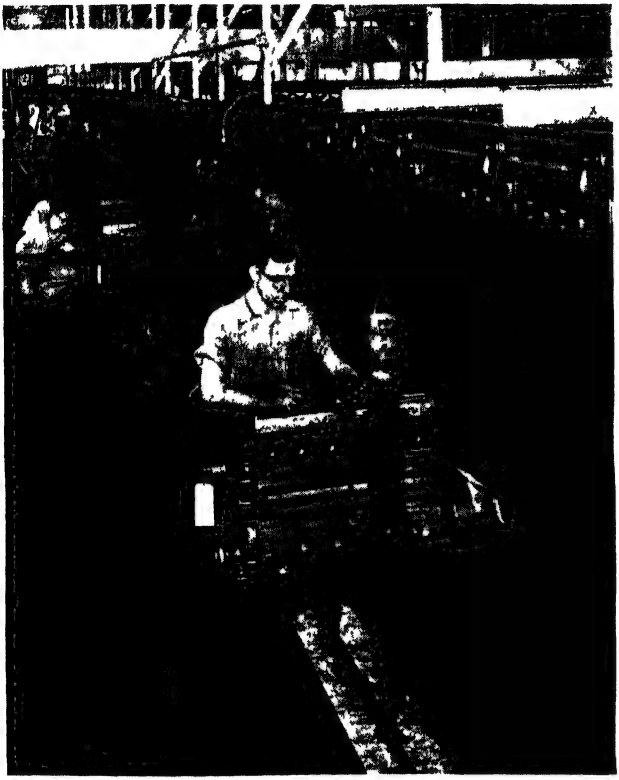


FIG. 62. Another type of conveyor used in engine assembly. Note the guide for the lower end of the engine stand.

Summarizing the advantages of this arrangement:

1. The time of receiving and inspecting incoming parts has been reduced from an elapsed period of 2 to 4 weeks down to hours.

2. As a consequence, inventory has been materially reduced.

3. Waste motion usually involved in receiving inspection has been reduced.

4. The amount of space formerly required for this portion of plant operation has been reduced.

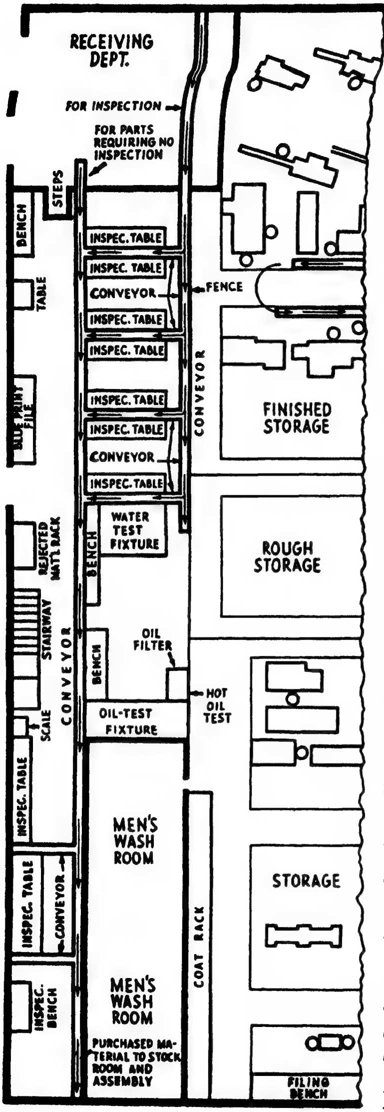


FIG. 63.—A conveyor is useful in the inspection department.

A similar arrangement was then established for inspection of manufactured parts in the small-parts division. These parts include such diversified items as bushings, connecting-rod pins, fan pulleys, oil-pump parts, governor levers, governor housings, valve tappets, and other miscellaneous items required in engine manufacture.

In setting up the systematic inspection layout for this division, it was first necessary to establish a smooth flow of work along the production lines in that section and to ensure that those parts that required inspection all moved toward the same point with a minimum of trucking. All parts are deposited in wire baskets and stacked at the entrance to a washer. After passing through the washer, the baskets roll out on the conveyor where sufficient space has been provided to let the parts drain and cool.

The noninspected parts move along the conveyor at the end of the inspectors' benches. They are picked off by the proper man, inspected, and, when passed, are put in metal tote boxes and moved out on the roller conveyor at the opposite end of the inspection bench.

Parts coming off the end of this line are ready to truck to assembly or to the stock room.

This central inspection group has resulted in the following advantages:

1. Elimination of waste motion by having the material flow to the inspector rather than having him go from place to place to check material.

2. Simplified supervision and control by congregating all inspectors in one place.

3. Elimination of waste motion by placing tools at the inspector's immediate disposal and in convenient operating position.

4. Reduction of the working area usually required for the many inspection jobs necessary in such a department.

5. Elimination of storage space usually required around the inspector's bench.

6. Improved cleanliness of the department. This system eliminates congestion in the manufacturing departments, which helps to keep a cleaner shop.

7. Speeded-up inspection, so that it is almost as fast as the production line, thereby eliminating dead spots in the flow of material.

8. Lower unit costs by the improved performance in the inspection department.

Conveyors in a Job Shop.—Continuous-flow principles can, with modification, be employed economically in the job shop, says K. W. Mink, of the railway control division of the General Electric Company plant at Erie, Pa. However, this cannot be done without introducing the necessary materials-handling equipment. The rapid handling of parts and tools between operations and final delivery of the parts to inspection and final assembly benches is essential if the advantages of "continuous flow" are to be realized.

An example of the application of these principles to job-lot manufacture of both simple and complex assemblies is given herewith. Here approximately 2000 different types of units, some having as many as 1000 different forms, are manufactured largely on an "as required" nonrepetitive basis. The average load is about 2400 orders per week, with the normal quantity per order ranging from one to ten pieces.

Incoming raw material is received and stored on the ground floor. From here it is delivered to the punch-press section or placed in standard tote pans for transfer on a reciprocating elevator to the mezzanine floor. A gravity-feed roller-conveyor line passes the material into the central dispatch station. Here the necessary work papers are added, tools are specified, and the work is routed by means of numbered cards to the various work stations in the department. Each job is returned to the control

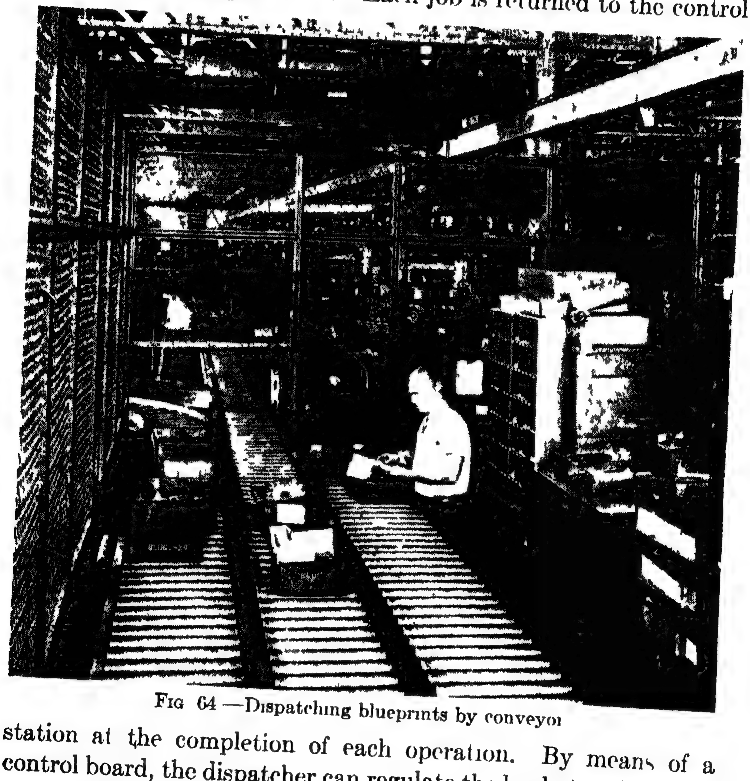


FIG 64 —Dispatching blueprints by conveyor

station at the completion of each operation. By means of a control board, the dispatcher can regulate the load at each station according to its capacity or locate any order quickly.

The illustrations, Figs. 64 to 67, show some of the conveyors used, and the floor plan, Fig. 68, shows the location of the different departments as well as the testing equipment and the stock racks. Among the advantages are:

1. Small lots are processed with minimum expenditures for transportation.

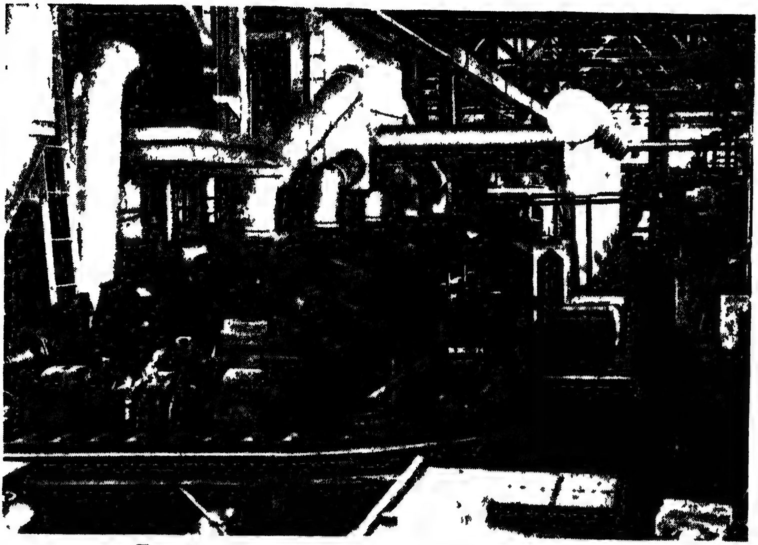


FIG. 65. Conveyors in a large plating department.

FIG. 66.—Auxiliary roller conveyors on each side of a main roller conveyor which goes the full length of the room.

2. Central dispatching of both materials and tools eliminates time normally lost by machine operators.

3. Convenient height of work-station conveyors lessens fatigue in moving materials.

4. Good housekeeping is possible when materials and tools are kept off the floor.

5. Reduction of aisle area provides better utilization of floor space.

6. Manufacturing cycle has been reduced; delays have been eliminated.

FIG. 67—Conveyor for an inspection department

7. Orders have little or no opportunity to become sidetracked or lost.

VERTICAL STORAGE

Floor Space Saved.—Vertical, or three-dimensional, storage means using racks and boxes with skid bases so they can be placed one above the other and only occupy the floor space of one. This saves spreading material all over the floors and benches which are more valuable for other things.

The layout shows the shop of the Lewis-Shepard Co., which makes materials-handling apparatus. Their chief engineer, Nathaniel Warshaw, states that the shop area would have to be increased at least 25 per cent if this method of storing parts were not used. The system is used for process parts, tools, and fixtures

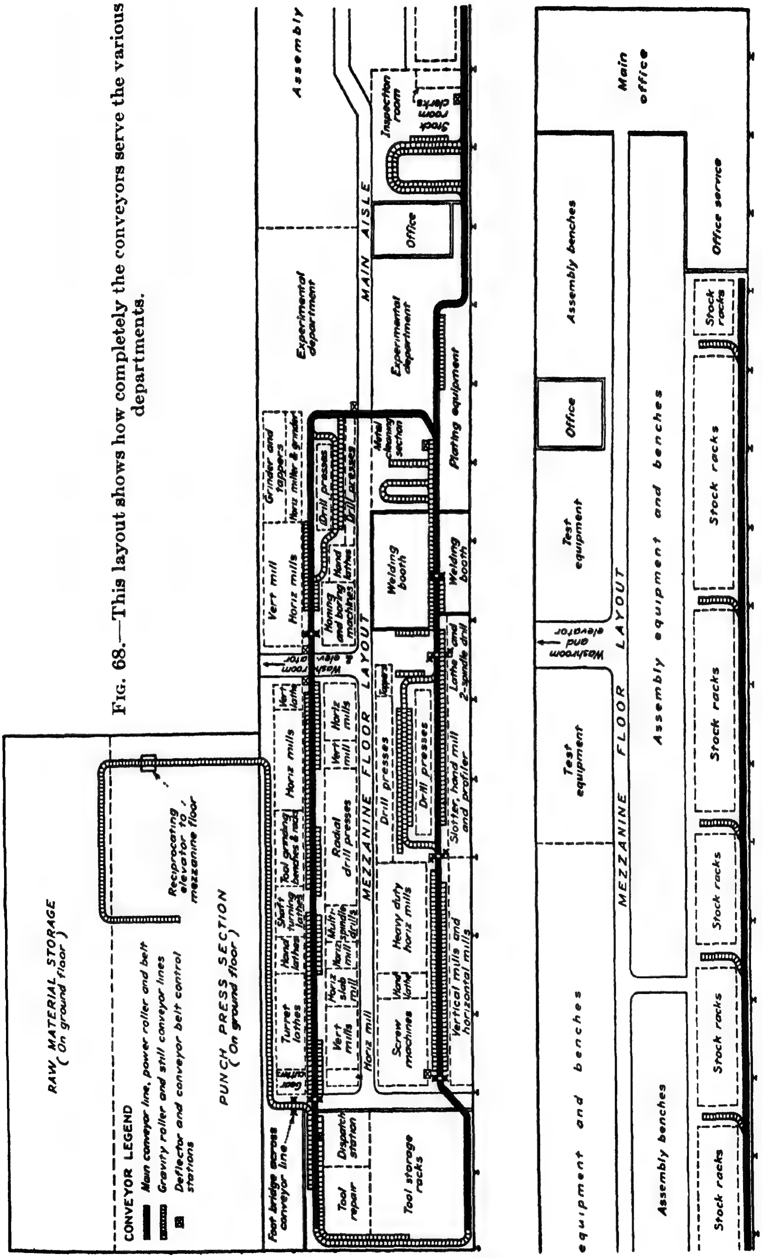


FIG. 68.—This layout shows how completely the conveyors serve the various departments.

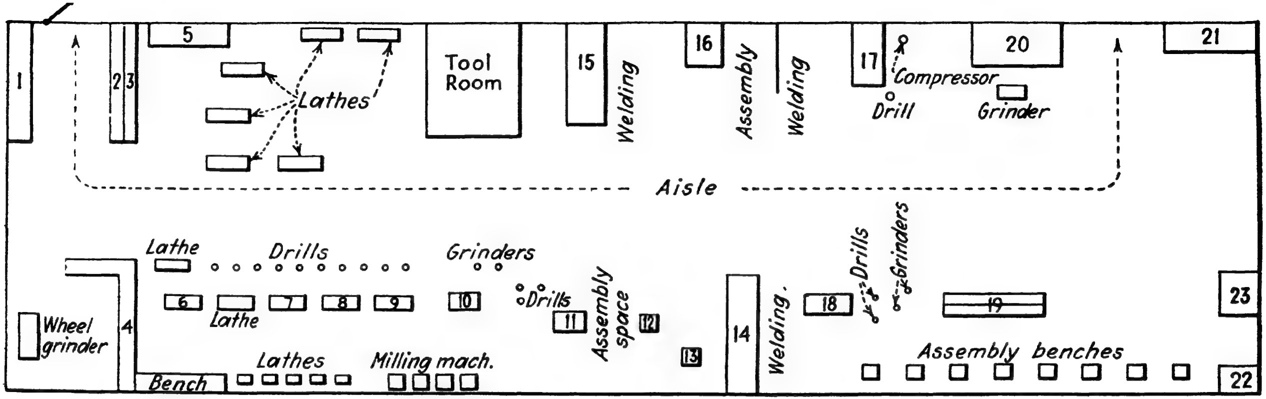


FIG. 69.—The machine shop of the Lewis-Shepard Company has 23 racks in positions convenient to the various operations in order to supply process parts, tools, dies, and fixtures without waste of time or effort.

1, 2, 3. Racks for boxes with skid bases.
4. Small bins.
5. Rack for bar stock
6. Stacked boxes with skid bases
7, 8 Shelves with skid bases for drill jigs
9, 10. Stacked boxes with skid bases, 2 and 3 tiers high.
11, 12, 13. Shelves for parts and tools
14 Rack for unit assemblies of stackers
15 Shelves and racks for welding jigs
16 Racks for parts
17. Racks for stock used in welding.
18 Stacked skid boxes.
19, 20 Shelves and compartments for stock and parts
21 Racks for angle steel.
22 Shelves for tools
23 Shelves for stock and jigs.

in more or less constant use. Its economy can only be realized when the unit loads can be handled quickly and easily.

Twenty-three racks with shelves and boxes are distributed around the main machine shop as shown in the floor layout, Fig. 69. The room measures 200 × 50 ft. In addition to the machine tools, considerable space is utilized for arc welding and assembly. The relation of these racks to the various machines is shown, as well as the purposes for which they are used. Rack 14 is illustrated in Fig. 70. Each vertical section contains all the

FIG. 70.—A great deal of space can be saved by vertical storage.

unit parts and the hoisting mechanism needed for the assembly of one stacker. The hoisting mechanism is visible in the top compartment and is lifted in and out by the stacker at the right. In the lower portion of each section is a portable rack with skid base. The various small parts required are placed in the several shelves. All these items are gathered together in the main stock room and moved by lift truck to the rack. One man operates either the stacker or the truck.

A large rack at one end of the shop is mostly used for castings. The individual bins are put in place and taken out with a stacker, except those nearest the floor which may be handled with lift trucks. High tiering is available, but in many cases only two or

three levels are used. Practically everything in the shop that is movable has skid bases to facilitate handling by means of stackers or lift trucks.

Flexibility.—The great flexibility of this arrangement will be apparent. As conditions in the shop change, which they are constantly doing, the height or location of the racks may be changed. When a great deal of work is going through the shop the racks can be made high to accommodate the materials or parts required without congesting the floor space. They can always be placed where most convenient. If it is necessary to clear a certain part of the floor for a special assembly, say of a large unit, it is an easy matter to move the racks where they will be out of the way and yet where the materials that they carry are within easy reach. And all of this may be done with very little expenditure of time or labor, and the finished parts are always at hand to the assembly points.

Convenience to Machines.—One of the most convenient arrangements is in connection with the large punch presses. The dies are kept on a rack adjacent to them. When it is necessary to change a die, it is taken from the rack and placed on the press by means of a stacker by one man. This not only saves time and labor but practically eliminates danger of dropping the die and injuring it or the workman. Racks are similarly provided adjacent to the other machines for tools, jigs and fixtures, and also for metal. These are always brought in and put in place with lift trucks or stackers, but they are usually taken out by hand since only one at a time is used and no great weight is then involved.

One important consideration which must always be borne in mind is that the racks must be placed so that they can always be reached from an aisle or permanently clear space with room enough for the lift truck or stacker to operate. In order to make this the more simple, the skid bases are made so that they may be lifted either from the ends or the sides, and need not be kept clear of obstructions from just one end.

WORKBENCHES

Construction.—Ideas as to workbench construction have changed with the years. The usual height remains at 33 in. For some work, benches with sheet-steel tops are used to advantage. In many cases wooden tops are best. Some cover them

with battleship lineoleum and find it good for assembling small work. Where small parts such as shafts and balls tend to roll, corrugated-paper packing boards are very useful. With the corrugations on the top, the parts are held against movement, and the paper is so resilient that no damage can come to the parts. This paper is inexpensive and easily renewed.

Modern benches are usually made with legs of pressed steel. Both wood and cast-iron constructions have largely disappeared. Steel is lighter, more attractive, and less liable to damage.

Location.—Bench location has also changed in many shops. Formerly nearly all benches were against the wall so that men

FIG. 71.—Toolroom with right-angle benches.

faced the light from the windows. This made dark spots on the benches between the windows, which were not so closely spaced as at present in the modern buildings. Facing the light was not good in all cases.

Many now prefer benches at right angles to the windows so that the light strikes the work from the side. By having double benches at each window, both right- and left-handed men can get their favorite light. As most men are right-handed, single benches so placed as to bring the light from the left may be best. Figure 71 shows how right-angled benches are arranged in the toolroom of one large shop. The waste or trash bins at the end of each bench help to keep the shop looking spick and span

CHAPTER 5

TOOLROOMS AND TOOL CRIBS

ACCESSIBILITY OF TOOLS

Two essentials in the planning of tool storage in the tool crib are safety of the tools and accessibility. By safety is meant the protection of cutting edges from damage. And the tools should be visible and easily reached.

Although steel shelves and racks are preferable to wood in most ways, it is advisable, even if not always necessary, to use wood or other nonmetallic material to prevent contact between the cutting edges and the steel. Shelves, racks, or boxes for holding tools can be readily lined with plywood or cork for contact surfaces.

Another consideration is that of keeping the shelves and tools free from dirt and dust. Low-pressure air is sometimes used to blow dust from around the tools. The objection to this method is that much of it settles back on the tools or in other equally inconvenient places. Vacuum cleaners are frequently used with satisfactory results.

Fixed racks are not easy to clean around in a toolroom or crib. One large concern has all its tool racks mounted on large ball-bearing casters. This makes it possible to move them at will, even though heavy. Floors can be cleaned or painted more easily, and the racks can be moved to other parts of the shop, if it should be desirable.

These racks are of steel painted with a gloss white and can be kept in a most attractive condition with little work. Although this is an additional expense, it pays real dividends in added care of tools by the men and the general effect on the shop morale. Being mounted on casters, they can be shifted to conform with any rearrangement of the shop without loss of time or damage of any kind. This cannot be said of racks permanently fixed or built into the shop.

Micrometers are stored flat in this toolroom on closely spaced shelves with proper-sized openings to receive them. These make

replacement easy, since a vacancy is readily noticed. When they are laid flat on their sides, there is no tendency to distortion, no matter how slight, as there is where they hang on pegs or hooks.

Locating the Tool Crib.—When laying out a factory, it is the practice to have the material enter at one end of the building and exit at the other. Where the factory is laid out in long, comparatively narrow units, or where manufacturing conditions permit a sufficient number of parallel operations to fill the crosssection of the building without backtracking, such an arrangement is ideal.

It may even be set down as fundamental that the greatest efficiency is obtained by limiting the width of a department to that along which materials may progress always in the direction of final assembly. In academic language this means a smooth unidirectional flow of material; in shop language, straight-line production.

The disadvantage of such an arrangement is the location of the tool crib. It is usually stuck at one corner, because if it were located in the center of operations, where it belongs, it would interfere with manufacturing operations. It costs as much, however, for machine operators to walk back and forth to the tool crib, as it does for laborers to backtrack material.

So when the Black & Decker Co. rearranged its shop layout, it put the tool crib in the center of the machine department, as can be seen from the layout in Fig. 72. The arrows show the flow of material during manufacture. The aisles allow easy access to the tool crib from any part of the machine department. The machines needing most frequent access to the tool crib are located nearer to it than those whose work is generally in long runs, as, for example, the automatic screw machines.

Toolroom Records.—Toolroom records include both an inventory of the tools and equipment and its condition and the system of keeping track of tools out in the shop. The former is usually some form of card index that shows the location of each tool so that the work can be carried on in case the regular attendant is not there. For keeping track of the tools in the shop the brass check is the most common and most easily understood. This is a very simple method of showing where each tool is when out of the tool crib. Each man has a bunch of ten or more brass checks

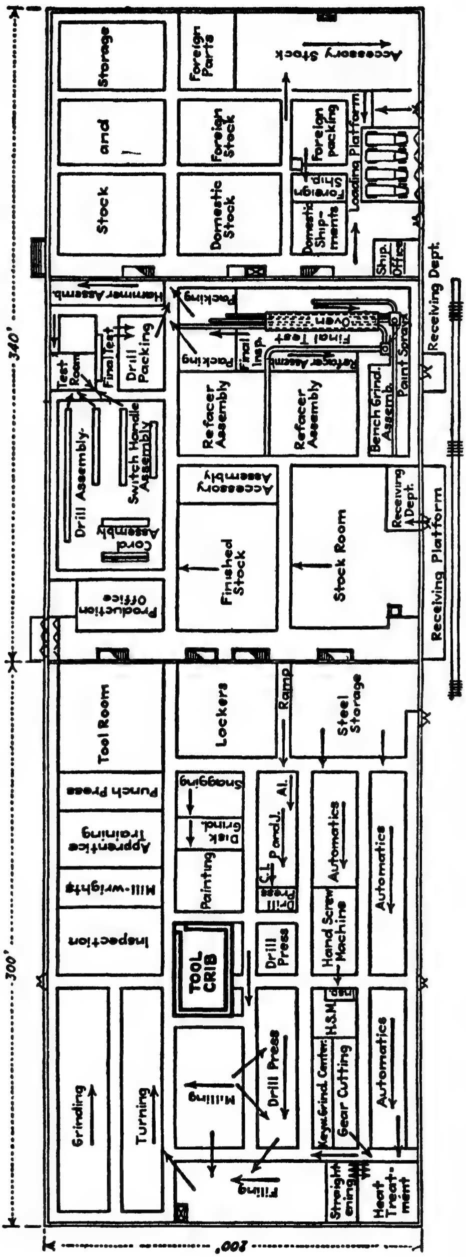


Fig. 72.—Rearrangement of manufacturing operation as finally decided upon. The tool crib is the pylon around which all material passes on its progress to finished-part stores.

with an identifying number, usually his pay-roll number. When he draws a tool from the crib, one of his checks is hung, or placed, in the space normally occupied by the tool. The check is given back when he returns the tool. Many still consider it the simplest system for keeping track of tools.

Others prefer the McCaskey or Kardex system in which printed forms replace the brass check. When filled out, these forms show the name of the tool and who has it. The worker has a duplicate so as to know just what is charged against him. If desired, the slips can be filed to show who has used the tool over any desired period. The workman destroys his slip on returning the tool to the crib. Similar slips, in duplicate, are used for a number of purposes in various shops. The uses of this form of record and its advantages will be discussed later by one who has given them much time and study.

Each shop must choose the kind of record that seems best suited to its needs. But it must be remembered that even the simplest kind of records need attention, as none of them keep themselves. Several types of records will be shown in their proper place.

SYSTEM FOR THE MASTER TOOL CRIB

A toolcrib can be a satisfactory adjunct to the production departments it serves, or it can be a great source of annoyance. Which it is depends a lot on the intelligence and effort expended upon it. Of course, in larger plants a poor setup will not be tolerated so readily as in a smaller one because the resultant snarls are much more deadly to output. Even so, a poorly run tool crib is a constant source of expense and annoyance in any plant.

Back in the 1920's, the aircraft-engine business of the Wright Aeronautical Corporation became a mass-production proposition. New buildings had to be put up, new equipment installed, and many more men hired. As the hum of production grew louder, the demands on the tool crib increased in volume.

What the System Does.—The problem was too big, the investment in tools too large to permit haphazard methods. For these reasons the production tool supervisor visited a number of well-run plants over a number of years. Thus, through constant study and adaptation, he developed a system that accounts for all tools, gets the tools into the hands of the men without delay,

and keeps the inventory of perishable tools down to a 1 month's supply. His organization includes a master tool crib and eleven departmental tool cribs.

There is a good deal of paper work in the Wright system, but it cannot be criticized lightly on that score. Reflection will show that if cumbersome, the system by this time would have fallen of its own weight; if insufficient, the economies obtained would be lacking. Moreover, during the present high output of engines, the tool-crib methods prove adequate.

Fundamentally, the setup combines the features of the Kardex and the McCaskey systems. Kardex records are used in the master tool crib to record the stock of special tools on hand, with a supplementary Kardex file in each departmental tool crib to record the activity of the special tools. Another Kardex file in the master crib gives the stock on hand and the activity of standard or perishable tools. McCaskey forms, in combination with brass workmen's checks, are used at the tool-crib windows for the actual withdrawal of tools and operation sheets. Various other forms also figure in the daily work of the master tool crib to tie in its activities with those of other departments.

Accurate, up-to-the-minute records are necessary to the master tool crib because it is charged with all perishable tools. It in turn passes the charges along to the individual departments as tools are drawn out on requisition. Special tools are not charged to the master tool crib but to the charge number set up for the particular model of engine on which they will be used. In this case, the tool crib is responsible only for knowing where these tools are and for ordering replacements as required.

Special tools require more effort to secure than do perishable tools, and the master tool crib plays its part in the process. There are two sources of supply—either an outside vendor, or the home toolroom. The choice is made at the discretion of the management, but at present the trend is to rely principally on the outside vendor because the Wright toolroom is kept busy in rebuilding jigs, fixtures, and production machines.

Each model of engine has its own account number, to which special tools, jigs, and fixtures are charged. In the tool-design department there is a representative of the purchasing department, and when a tool is to be bought outside, this man prepares a purchase requisition in quadruplicate. The original copy goes

to the vendor; of the remaining three, one goes to the tool inspection, one to the master tool crib, and one to file in the purchasing department.

Upon receipt of the special tool, the receiving department checks it against the purchase order, and six copies of a receiving report are made out and distributed as follows:

No. 1. To the master tool crib as notification that the tool has been received. The crib makes a notation on its copy of the purchase requisition that the tool has been received, with the date, so that inquiries from shop departments can be answered.

Nos. 2 and 3. These are sent with the material to tool inspection. When the tool is O.K.'d, the No. 2 copy is sent to the accounting department, while the No. 3 copy is held in the crib for reference.

Nos. 4 and 5. These are sent to the purchasing department.

No. 6. Sent to the accounting department.

The No. 1 copy of the receiving report goes directly to the master tool crib, whereas the Nos. 2 and 3 copies accompany the material to the tool-inspection department. The reason for this procedure is that the two departments are separated by two floors. After inspection the accepted or rejected tools are forwarded to the master tool crib with these two copies of the receiving report.

A Double Check.—When the master crib receives the inspected tools, it checks the receiving order against the purchase requisition as a double check and to show that the material has actually arrived at its destination. If the quantity is short, the actual amount received is noted with the date on the purchase requisition. When the balance is received, it is also checked on the crib's copy of the purchase requisition. Then the No. 2 copy of the receiving report is O.K.'d and sent to the accounting department. Rejected material is noted on the receiving report and is held until the sales order comes through to return it.

But if accepted, the procedure for setting up the records in the master tool crib on the special tool is this:

1. A form, Fig. 73, is sent to the foreman of the department that will use the tool, to notify him that the tool has been delivered to his departmental tool crib.

2. A master Kardex, Fig. 74, for file in the master crib is made out. This form shows stock on hand.

FORM 512

NOTIFICATION OF TOOL DELIVERY

TOOL NO T-45149 Reamer

PART NO 65297

OPER NO 65

HAS BEEN DELIVERED TO TOOL CRIB NO 203

DATE: 11-9-36

REMARKS:

FIG 73 —When a department foreman receives this notification, he knows that a special tool wanted for a certain job has been received in his own tool crib

TOOL NO T-26446 Turn-ing Fixture DESCRIPTION BIN NO

MAX | MIN | MODEL J-6 | PART NO. 63031 | PART NAME Counterweight-Rear

ORDERED				STOCK					STOCK				
DATE	P O NO	QUAN	VENDOR	DATE	CRIB	IN	OUT	BAL	DATE	CRIB	IN	OUT	BAL
				7/12/35	B71442 Acme	1							
				"	102		1	0					

FIG 74 —Stock on hand of a special tool is shown on this master-crib Kardex form The handwritten notations give the purchase order number and vendor for convenience in reordering

T-26446 Turn-ing Fixture
TOOL NO DESCRIPTION BIN NO

MAX MIN 63031

DATE	BAL	TOOL ACTIVITY RECORD	
7/12/35	1	54 8/11	✓
		92 10/5	✓
Dec. 30, 1935			
		54 3/4/36	✓
		21 5/9/36	✓
		08 7/15/36	✓
		27 10/27	

TOOL NO T-26446 | DESCRIPTION Turning Fixture | BIN NO

FIG 75 —A second Kardex is maintained in the departmental tool crib to give an activity record for the special tool

3. A Kardex, Fig. 75, is set up for the file in the departmental tool crib and shows the tool-activity record.

The Kardex file maintained in the master tool crib for special tools shows the following record for each tool: tool number, the purchase-order number, the quantity bought, the vendor, and the departmental tool crib to which the tool is assigned. The second Kardex, which shows the tool activity in the departmental tool crib, gives the date when the tool is withdrawn, and this date is checked off upon return of the tool. At inventory time a special stamp is placed below the record of withdrawals, and if two

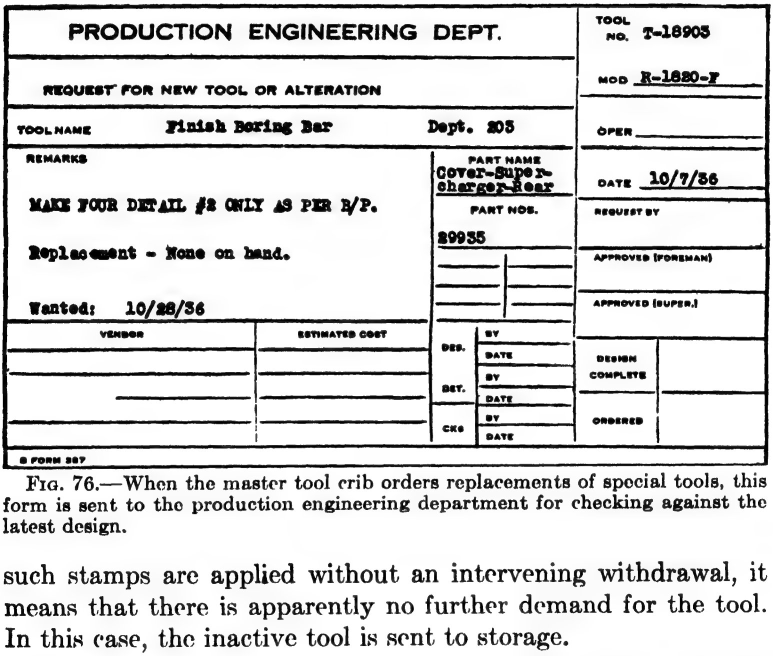

PRODUCTION ENGINEERING DEPT.
TOOL NO. T-18903
REQUEST FOR NEW TOOL OR ALTERATION
MOD R-1820-F
TOOL NAME Finish Boring Bar Dept. 205
OPER
REMARKS
PART NAME Cover-Supercharger-Rear
DATE 10/7/36
MAKE FOUR DETAIL #2 ONLY AS PER B/P.
PART NOS.
REQUEST BY
29935
Replacement - None on hand.
APPROVED (FOREMAN)
Wanted: 10/28/36
APPROVED (SUPER.)
VENDOR
ESTIMATED COST
DES. BY DATE
DESIGN COMPLETE
DET. BY DATE
CKS BY DATE
ORDERED
B FORM 387

FIG. 76.—When the master tool crib orders replacements of special tools, this form is sent to the production engineering department for checking against the latest design.

such stamps are applied without an intervening withdrawal, it means that there is apparently no further demand for the tool. In this case, the inactive tool is sent to storage.

After the activity of the special tool is discovered, desirable maximum and minimum quantities are set up on the Kardex in the master crib so that tools are available at all times for production. Moreover, the stock record on this master Kardex shows the number of replacement tools held in bins in the master crib. The columns for "Stock" show the number checked in, the number taken out by the departmental crib, and the balance on hand. When replacement tools are to be ordered, the file copy of the previous purchase order aids in determining where to order

the tools and also the time that must be allotted before they will be received.

Replacements for special tools are ordered by the master tool crib on the form shown in Fig. 76. A copy is held in file while the original and a follow-up card, Fig. 77, go to the production-engineering department for checking against the latest design. When passed, the two forms go to the purchasing department which notes on the follow-up card when the tools were ordered and when due. A copy of the purchase order is sent back to the master crib for checking against the receiving report.

VENDOR	SYMBOL
PUR. ORD. NO.	A. L.
DATE REQUISITION	DATE FORMAL ORDER
VENDOR'S PROM SHIPPING DATE	
FOLLOW UP RECORD	
1ST FOL.	1ST PROM
2ND FOL.	2ND PROM
3RD FOL.	3RD PROM.
4TH FOL.	4TH PROM
DATE WANTED 10/28/36	DATE REL. BY T. DES.

B FORM 408 REV.

TOOL NO T-18903

TOOL NAME Finish Boring Bar

PART NUMBER	QUANTITY	
29935	4, Det. #2	
TOOL ROOM HRS.	201 DEPT HRS.	..... DEPT. HRS.
DATE REC'D	QUANT REC D	O. K INSP.

MODEL	DATE REL. TO T. DESIGN
R-1820-F	10/7/36

FIG. 77.—This card accompanies the request shown in Fig. 76, and is used by the purchasing department for follow-up.

For Tools Made Inside.—So much for special tools and replacements bought outside. Those that are made in the plant have different paper work. A Departmental Order, Fig. 78, is prepared by the production engineering department. Space is provided for a sketch of the work to be done. The original copy is sent through to the toolroom foreman, while the carbon copy is held for file. If a blueprint is available, it is sent along with the original order. Furthermore, a timecard is included, to give a means of checking the actual time against the estimated time. These data are used in future decisions of the management on whether to have special tools made outside or in the home toolroom.

When the special tool is finished, the work order and the print go with it to the tool-inspection department. When the master crib gets the accepted tool, a notification of tool delivery is made out and sent to the foreman of the interested department, while the tool itself is sent to the issuing tool crib. The work order then goes back to the production-engineering file. A master Kardex and a departmental tool-crib Kardex are made out for the tool, just as for tools bought outside.

A 1 month's supply is the standard float of perishable tools maintained by the master tool crib. When reordering, the

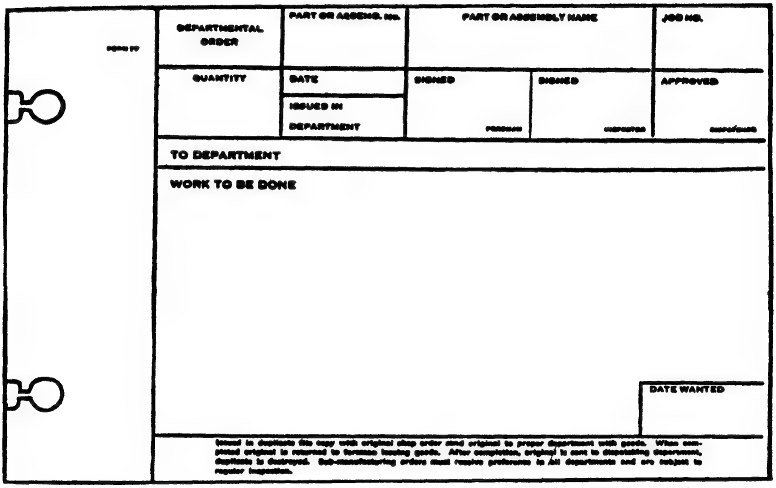


FIG. 78.—When special tools are to be made in the Wright toolroom, a "Departmental Order" is made out instead of a purchase order.

follow-up man makes out a purchase requisition that is similar to the form used by the production-engineering department in requesting new special tools. The only difference is that the standard perishable tool requisition is rubber-stamped as in Fig. 79, and filled in with the quantity on hand and the quantity used in the previous month. These data are determined from a separate Kardex file maintained solely on perishable tools. This Kardex differs from that in Fig. 75 only in that space is provided to enter the unit price.

In figuring the new quantity to be ordered, the follow-up man gives consideration to the number of engines to be built in the coming month as against those during the preceding month,

when, of course, the tool usage was known. He also enters a standard balance on the Kardex to aid in maintaining a sufficient supply of tools. This standard balance is calculated from the length of time for delivery. Such items as grinding wheels may take from 4 to 10 weeks after receipt of order, whereas emery cloth, taps, and standard drills can be delivered at a week's notice.

More leeway is allowed in the standard float when ordering perishable special tools. For example, a twist drill of nonstand-

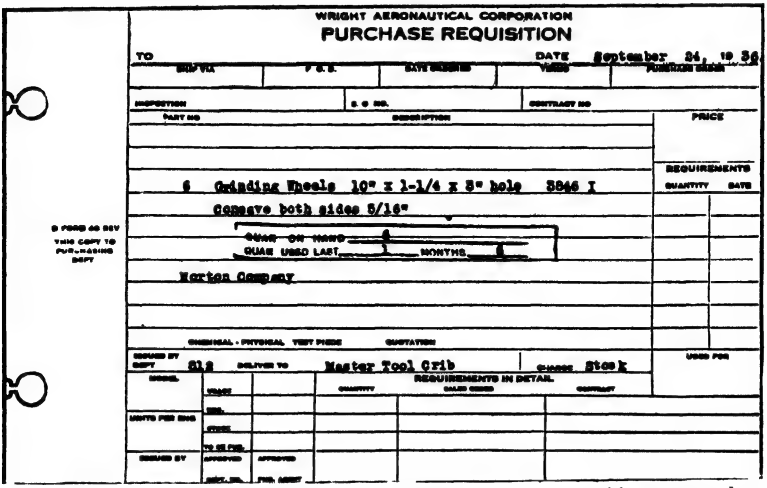


FIG. 79.—Purchase requisitions for perishable tools are rubber-stamped as shown at the center. The previous month's usage, as obtained from a Kardex activity and stock record, governs the quantity ordered.

ard length will be ordered in say 2-doz. lots, even though the usage is only six per month. The reason is that the setup cost in the vendor's plant is distributed over a greater number of tools and therefore the unit price per tool is much lower. Very rarely is the master crib caught with tools that cannot be used.

The purchase requisition is checked over by the purchasing department, and then bids are taken. Usually there is a first, second, and third choice of vendor, according to the shop's experience with the products of the various makers.

Foremen Know Tool Costs.—All tools are drawn by departmental crib attendants, and supplies such as grinding wheels are ordered by the department foreman on a requisition, Fig. 80, that lists the quantity ordered, the department, and the work

order number to which the material is to be charged. The date of withdrawal is put on the master-crib Kardex which shows stock activity. Other entries made on the Kardex are the department that received the material and the quantity. Since the unit price of the material has already been recorded on the Kardex, it is a simple matter to enter this unit price on the raw-material requisition, which is then sent to the accounting department. Once a week the total cost of perishable tools drawn by each department is calculated, and a copy is given to the foreman concerned. This report sets up the budget figures for each department and the actual tool costs for the week in question and for

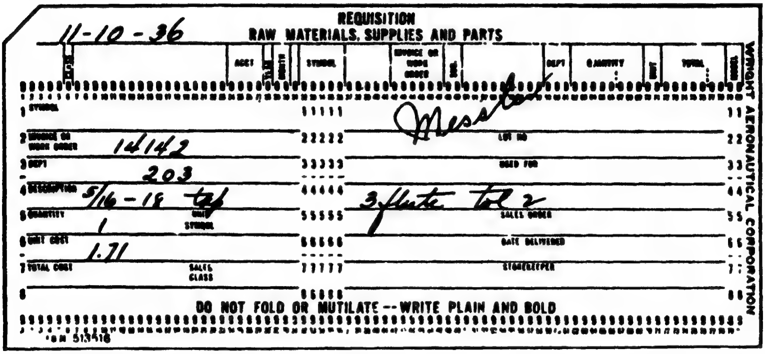

REQUISITION
RAW MATERIALS, SUPPLIES AND PARTS
11-10-36
14142
203
5/16-18 tap
1
1.71
3 flute tap 2
DO NOT FOLD OR MUTILATE--WRITE PLAIN AND BOLD
WRIGHT AERONAUTICAL CORPORATION

FIG. 80.—Perishable tools are drawn by the department foreman on this requisition form. Each week the total value drawn out and the budget figure are reported to him.

the three previous weeks for purposes of comparison. It also gives an itemized list for each department of all tools drawn, the unit cost, and the total cost. This practice has had wide influence on bringing down tool consumption because it compelled the foremen to analyze the reasons.

Method of Issuing Tools.—Up to this point, the discussion of methods at the Wright master tool crib has centered upon getting special and standard tools in and keeping track of them and their activity. The method of issue to the men is also of interest because, although apparently involved, in reality it expedites the physical handling of the tools and their checkup.

When assigning a job, the foreman gives the operator a routing card for the work. This card bears the part number, the order number, and a list of all the operations to be done. Those that have already been performed are punched out, so that the

operator knows immediately which one he is to do. He goes to the tool crib and makes out one order, Fig. 81, for an operation sheet giving him full instructions and another order, Fig. 82, for tools. These orders follow the McCaskey system. Brass checks are deposited against each tool order.

The Operation Sheet Order is made out in triplicate and marked "BP" if a blueprint is wanted. The original copy of the operation-sheet order is retained by the operator, and the other two are passed over to the tool-crib attendant. The second copy is put into an envelope with the operator's number on it, a file of such envelopes being maintained. The third copy of the order is placed in an operation folder which is filed according to the part number. With this system it is always possible to find out who has a particular operation sheet.

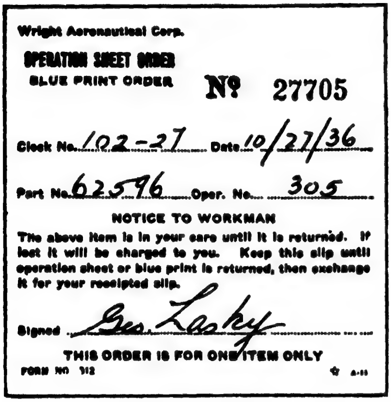

Wright Aeronautical Corp.
OPERATION SHEET ORDER
BLUE PRINT ORDER № 27705
Check No. 102-27 Date 10/27/36
Part No. 62596 Oper. No. 305
NOTICE TO WORKMAN
The above item is in your care until it is returned. If lost it will be charged to you. Keep this slip until operation sheet or blue print is returned, then exchange it for your receipted slip.
Signed Geo. Lasky
THIS ORDER IS FOR ONE ITEM ONLY
FORM NO 312

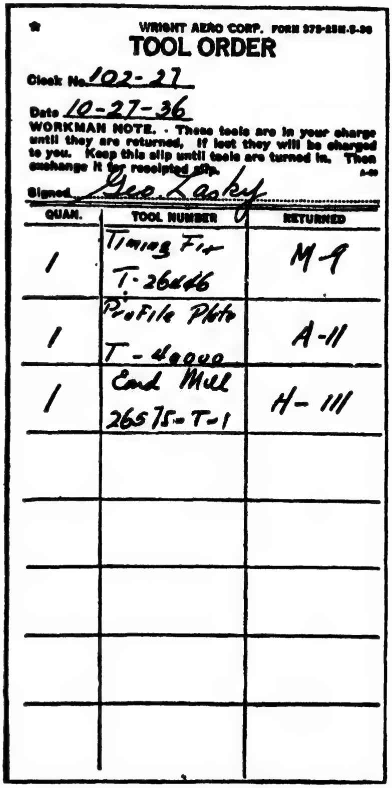
FIG. 81.—When starting a job, the operator makes out this McCaskey slip to secure an operation sheet and blueprint.

Tool-crib System.—Upon the operation sheet is a list of the tools required to perform the work. Each tool is numbered. The operator lists the tools on a Tool Order, which is also made out in triplicate, Fig. 82. Again the operator retains the original, while the two copies are filed with one of his brass checks. This file is also set up according to the number of the operator. An entry is made on the Kardex file to show the date of tool withdrawal, and the operator's number. An advantage of the Kardex file is that it gives a record of all operators who have had the tool previously. Suppose that an intricate fixture has a detail missing. By reference to the Kardex it is possible in many cases to locate the missing detail among the men who have had the fixture out.

When the tool is returned, the operator passes in his copy of the tool order, and the second and third copies, together with his brass check, are picked out from the file. The brass check and the second copy are given to him as a clearance, and the trans-

action is complete. The Kardex file entry is checked off at the convenience of the attendant. Likewise, when the operation sheet is returned, the slips are cleared out of the file. All micrometers and measuring instruments are given a serial number and maintained in the tool crib on a separate Kardex.

Brass checks might not be required, but occasionally a workman must go from his tool crib to one in an outside department in order to get the tools wanted. For such cases, each tool crib maintains a small "foreign file." Also, each man receives 10 checks when hired, and these must be accounted for when he leaves the company's employ. If he does not have all 10 checks he must go around to all tool cribs and get a release from each. When all checks are accounted for, the operator's payoff slip is signed by his tool-crib attendant and countersigned by the master crib.



WRIGHT AERO CORP. FORM [illegible]

TOOL ORDER

Clock No. 102-27

Date 10-27-36

WORKMAN NOTE. - These tools are in your charge until they are returned. If lost they will be charged to you. Keep this slip until tools are turned in. Then exchange it for receipted slip.

Signed Geo. Lasky

QUAN.	TOOL NUMBER	RETURNED
1	Timing Fix T-26446	M-9
1	Profile Plate T-40000	A-11
1	End Mill 26575-T-1	H-111

FIG. 82.—A list of tools required is given on the operation sheet and is ordered from the attendant with this slip.

Broken and Worn Tools. Once a week all broken or worn tools are turned in by each department to the master tool crib. Accompanying these is a Broken or Worn Out Tool slip. If anything can be salvaged, it is stored on suitable racks subject to call. There are large supplies of undersize plug gages, reamers, form tools, cutters, short drills, and similar tools. The salvage department also gains when a manufacturing department no longer has use for certain tools because the nature of its operations have been changed. The unwanted tools are sent to the central salvage, but no credit is given to the department that returns

them. Frequently, an undersize tool is desired and can be quickly located on the racks. In addition, plug gages are sorted out according to size, and when a sufficient number have been accumulated, they are sent out for chromium plating back to size or worked to new size.

Mounted diamonds for wheel dressers are issued directly by the master crib on the usual tool order. When the diamond becomes unserviceable or is broken, it is turned back to the master crib with a Broken or Worn Out Tool slip signed by the department foreman. A new diamond will then be given out on the same order. The broken or worn-out diamond is reset and the loss in weight is charged against the workman's department. The charge is computed from the original cost of the tool.

Because of the value of such tools, the operator can turn in diamonds each night to his departmental tool crib, since the brass check and a copy of the tool order have been forwarded to his crib for this purpose by the master crib. He gets the check back but leaves the tool order in, so that no one else can get the diamond charged against him.

Again, it will be said that there is necessity in the Wright plant for the high degree of control and paper work described. That it works smoothly can be attested by personal observation. The operators get their requirements almost immediately and there is no clutter of tools awaiting return to the racks.

TOOL-ROOM COSTS[1]

The cost of making tools must be known in order properly to control work going through the toolroom or to make estimates of the tool cost for work to be done in the production department. Unfortunately, in many shops estimates of tool costs are made without any real basis for the estimates; too often they are only guesses.

Tool costs are often quoted that are far out of line with actual costs when the tools are made, especially if no records are kept while tools are in process. Frequently no one is held responsible for keeping the actual costs within the estimates given.

Not only are tool costs too often out of line with estimates, but promised delivery dates frequently are passed without completion

[1] Charles W. Hardy, consulting industrial engineer.

of the tools, unless a follow-up system is used to ensure meeting the promised delivery date. If, when a tool order is in process, a progress report is required regularly, tools usually will be delivered on time.

Among the essentials for proper cost and production control in the toolroom is some means for recording estimated and actual costs and for recording final delivery of the tool to the customer or tool crib. For these purposes a few simple forms are required.

Estimating.—For estimating purposes, a form similar to that shown in Fig. 83 is necessary. These forms frequently can be reproduced in a mimeograph machine at little cost. In compiling the data on this form, it is essential that every operation requiring tools be considered. Also, such incidentals as experimental work and contingencies must be added in to keep the estimates in line with actual costs when they are compiled.

Estimated hours for making a given tool frequently can be determined by comparing that tool with a similar tool previously made, provided proper records have been kept. If these records are not available, the estimator must use good judgment and later check his estimates to ensure against continually estimating high or low. After tool costs have been accumulated for a few months, it will be quite easy to refer to previous tools for a guide in making estimates.

Overhead or burden costs must be added to direct labor costs in order to arrive at a total estimated cost. The burden rate can be determined only after a careful study of all indirect costs affecting the toolroom. Generally, in plants in the metal-products industry maintaining their own tool and die departments, the burden rate will range from 25 to 50 per cent of direct labor costs, depending on size and shop conditions. Here are some simple forms that will help in keeping tool costs in line.

For the No. 105 square compact, for which estimates are shown in Fig. 83, the estimated hours total 1067, and a rate per hour of \$1.75 has been used as the combined labor and burden cost per hour in the toolroom. Labor and overhead costs for the tools to make this compact thus are estimated to cost \$1667.25. To this must be added the estimated cost of material and supplies necessary to make the tools, as well as the cost of any work, such as diesinking and engraving, that may have to be done on contract in some other shop.

ESTIMATE Date Aug. 13, 1937

Item No. 1024 Description Square Compact-Design 105

No. of Oper.	Description	Hours	Mat.	Material Kind Size
	Cover			
1	Blank + Draw-Combination	100	$25	3½ x 3½ x 018
7	Swedge	75	10	Rich L
6	Cut Edges	30	3	
14	Stamp Design 105 Drop Hammer	50	10	
5	Trim Hinge Bench Power	40	5	
29	Curl " " "	20	2	
16	Notch	25	3	
	Bottom			
1	Blank + Draw Use Cover Die	—	—	3½ x 3½ x 018
7	Swedge " " "	—	—	Rich L
6	Cut Edges " " "	—	—	
14	Stamp Design Standard No. 16	—	—	
5	Trim Hinge	40	5	
29	Curl " Use Cover Die	—	—	
	Bezel			
1	Blank	75	15	3¼ x 3¼ x 016
13	Pierce	40	5	High brass
7	Bevel + Size	45	5	
	Assembly			
29	Cover + Bottom with Hinge Pin	20	2	
52	Mirror	10	1	
48	Lock Use No 807	—	—	
	4 Sets Polishing Blocks for Cov + Bottom	80	10	
	8 Sets Lacquering Stencils "	120	15	
	Experimental, Adjustments + Changes	200	25	
	Unforeseen 10%	97	14	
	Total	1067	155	
	Direct Labor & Burden @ $1.75 Hr. = $1,667.25			
	Material & Supplies 155.00			
	Cost of Stamping Job (Outside) 175.00			
	Total 1997.25			

FIG. 83.—When estimating tool costs, it is essential that all the tools required for a given job be taken into consideration. Also, allowances must be made for experimental work, adjustments, possible changes, and contingencies.

HARDY METAL SPECIALTIES INC.
TOOL & DIE ORDER

ESTIMATED HOURS 100 JOB NO. 2003

ITEM 1024 Square Compact Cover

CUSTOMER

DESCRIPTION Combination Blanking + Drawing in Standard four post Die Set

PRINT OR DRAWING NO. 102.4 1072-1 APPROVED BY C.W.K.

DATE ISSUED August 17, 37 DATE FINISHED

DIE MAKER:—STAMP THIS ORDER NO. ON BOTH PUNCH & DIE

FIG. 84.—Individual orders for tools are necessary if proper cost records are to be kept. To ensure proper functioning of the control system, it is essential that such orders be used.

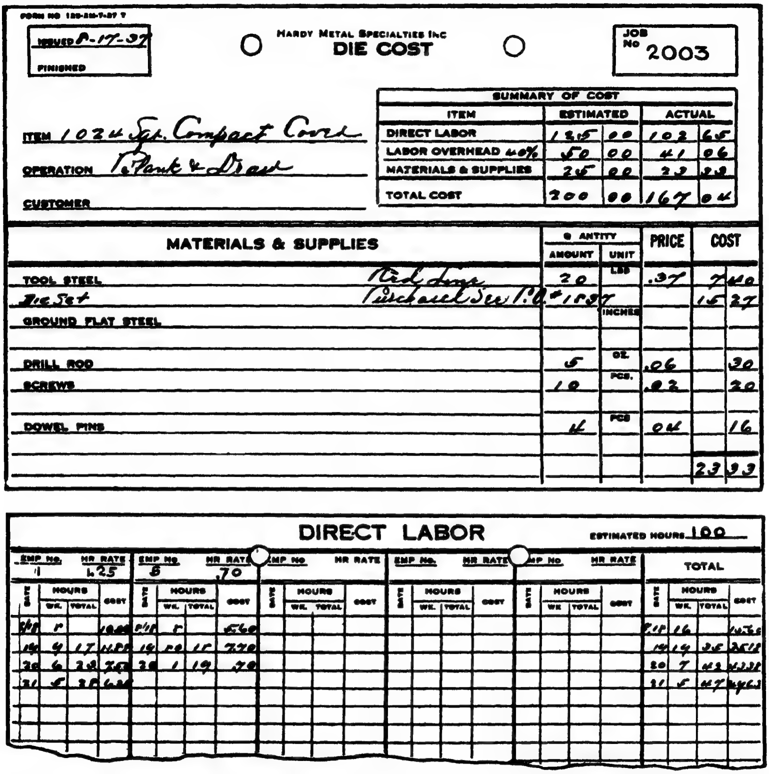
DATE 8/18/37 NAME John Smith EMP. NO. 5

JOB NO.	PART		O.T. HRS	HOURS			COST
	NO	DESCRIPTION		ON	OFF	WKD.	
2003	1024	Covers	–	8	4:30	8	5 60

HARDY METAL SPECIALTIES INC.
DAILY TIME TICKET · DIE & MAINTENANCE

FIG. 85.—It sometimes is an aid in simplifying the control system if the toolmaker is instructed to list materials and supplies used on the back of his daily time ticket. Both direct labor and materials are posted daily from these reports in order to ensure that the total actual cost of the tool will be recorded.

When the estimates have been approved and authority has been obtained, individual orders should be issued for each tool, die, jig, or fixture required. These orders constitute the toolroom's authority to proceed with the work. A typical tool and die order form is shown in Fig. 84. This order is given to a



FORM NO 129-2M-7-37 7

ISSUED 8-17-37

FINISHED

HARDY METAL SPECIALTIES INC
DIE COST

JOB No 2003

ITEM 1024 Sq. Compact Cover

OPERATION P. Blank & Draw

CUSTOMER

SUMMARY OF COST				
ITEM	ESTIMATED		ACTUAL	
DIRECT LABOR	125	00	102	65
LABOR OVERHEAD 40%	50	00	41	06
MATERIALS & SUPPLIES	25	00	23	33
TOTAL COST	200	00	167	04

MATERIALS & SUPPLIES		QUANTITY AMOUNT	UNIT	PRICE	COST	
TOOL STEEL	Red Line	20	LBS	.37	7	40
Die Set	Purchased See P.O. #1897				15	27
GROUND FLAT STEEL			INCHES			
DRILL ROD		5	OZ.	.06		30
SCREWS		10	PCS.	.02		20
DOWEL PINS		4	PCS	04		16
					23	33

DIRECT LABOR — ESTIMATED HOURS 100

EMP No. 1, HR RATE .625				EMP No. 5, HR RATE .70				EMP No., HR RATE				EMP No., HR RATE				EMP No., HR RATE				TOTAL			
DATE	HOURS WK.	HOURS TOTAL	COST	DATE	HOURS WK.	HOURS TOTAL	COST	DATE	HOURS WK.	HOURS TOTAL	COST	DATE	HOURS WK.	HOURS TOTAL	COST	DATE	HOURS WK.	HOURS TOTAL	COST	DATE	HOURS WK.	HOURS TOTAL	COST
8/18	8		[illegible]	8/18	8		5.60													8/18	16		[illegible]
19	9	17	[illegible]	19	10	18	7.70													19	19	35	[illegible]
20	6	23	[illegible]	20	1	19	.70													20	7	42	[illegible]
21	5	28	[illegible]																	21	5	47	[illegible]

FIG. 86.—This card is used for accumulating and summarizing the actual cost of each individual tool. When the tool finally is completed, the total actual cost of direct labor, overhead, and materials can be compared with estimates.

toolmaker to whom a job is assigned, and he is required to report the actual hours spent in making the tool on a daily time ticket such as that shown in Fig. 85. This ticket also can be used for tool-maintenance work and for other operations in the toolroom. If the toolmaker is instructed to list on the back of this time ticket all materials and supplies used, it can be made to serve the double purpose of giving an actual record of both time and material used in making the tool.

These time tickets, which are turned in daily to someone in the toolroom office, are posted regularly on the tool-cost record card shown in Fig. 86. Direct labor costs are recorded on the back of this form, and materials used are shown on the face. Extensions of the cost of materials and supplies should be made by the cost clerk, in order to ensure that proper piece prices are used.

All labor and material is accumulated on the cost record card, Fig. 86, until the job is completed. Then the summary of cost section of the card is filled in, and the card is placed in a permanent record file.

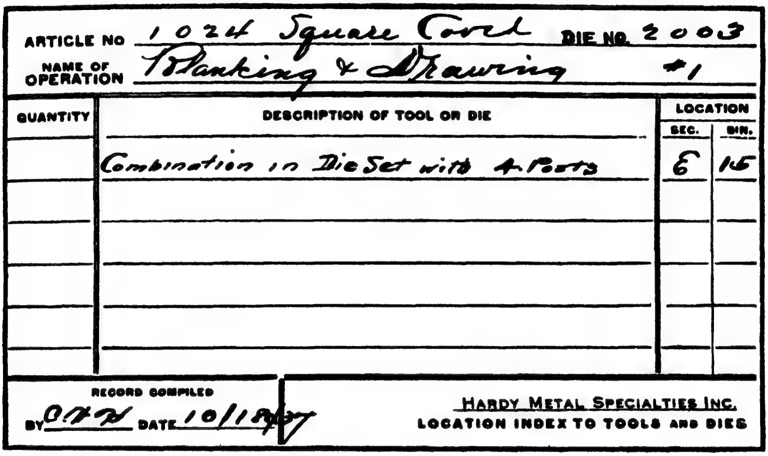


FIG. 87.—Tools are easily misplaced or damaged unless they are stored between jobs in a specially arranged crib or storeroom. For convenience, and to ensure against the loss of a tool, a record card should be kept to indicate the crib location assigned to that tool.

Should the actual hours exceed those estimated, the summary will bring this condition to light, since both estimated and actual costs are shown. Both the toolroom foreman and the estimator should review these cards before they are placed in the file, in order to investigate any costs that appear out of line and to keep informed regarding the efficiency of the department.

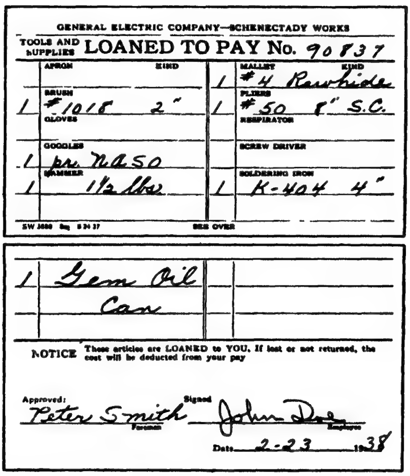
Most tools will last considerably longer than the first job for which they are used, and they should be stored in a tool crib until needed again. Each tool should be assigned a definite location on a shelf or in a bin and a locations record card, such as shown in Fig. 87, should be made up to show where each tool is kept. When it is necessary to change the regular location of a tool, the

card is revised accordingly. If the tool finally is discarded or changed to make it suitable for another part, this should be recorded on the card.

Controlling Production Schedules.—Some means of recording and controlling production schedules is essential if tools are to be delivered on time. Frequently a simple bar chart indicating promised delivery date and amount of work done on the tool will enable the supervisors to bring extra pressure to bear on tools that are not being made in line with the promised date.

A DOUBLE CHECK ON TOOLS

C. H. Borneman, supervisor of the tool and gage service department of the General Electric Co. at Schenectady, N.Y.,



GENERAL ELECTRIC COMPANY—SCHENECTADY WORKS

TOOLS AND SUPPLIES LOANED TO PAY No. 90837

	APRON	1	MALLET #4 Rawhide
1	BRUSH #1018 2"	1	PLIERS #50 8" S.C.
	GLOVES		RESPIRATOR
1	GOGGLES pr. NASO		SCREW DRIVER
1	HAMMER 1½ lbs	1	SOLDERING IRON K-404 4"

SEE OVER

1	Gem Oil Can		

NOTICE These articles are LOANED to YOU. If lost or not returned, the cost will be deducted from your pay

Approved: Peter Smith, Foreman. Signed John Doe, Employee

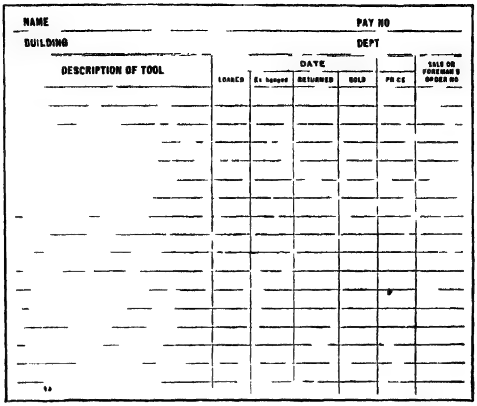
Date 2-23 1938

FIG. 88A.—Record card for loan of tools used by employees for a considerable period of time.

described their system in the *American Machinist*, showing how they keep track of tools and gages with a double check system that is neither costly nor cumbersome.

Tools ready at a moment's notice, yet all quickly accounted for, is the object of this system of control. This plant turns out tailor-made apparatus of many kinds in a wide range of sizes so that the tool crib system has to be on a jobbing shop basis. To prevent delays and unnecessary purchases, tools not in use must be available to all departments. The system, successfully employed for over a year, does all of this and has justified

the change-over from the slip and brass check system that it displaced.



NAME PAY NO

BUILDING DEPT

DESCRIPTION OF TOOL	DATE				PRICE	SALE OR FOREMAN'S ORDER NO
	LOANED	Exchanged	RETURNED	SOLD		

FIG. 88B.—Permanent-record card for tools loaned to employees for a considerable period of time, including entry for exchange and tools returned.

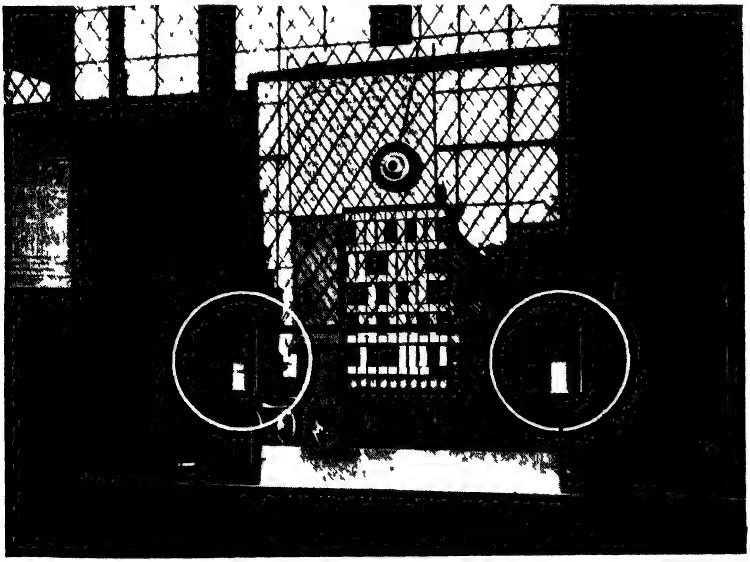


FIG. 89.—Tool-crib window with tool-order dispensers

Under the old system, each man had a number of brass checks, usually 10, charged to him but retained in the crib. When he needed a tool, he filled out a tool order Fig. 88A which was placed

in a file pocket near which his tool checks hung. A check was moved to the storage-space hook and the tool handed to the man. Figure 88*B* is a permanent record of tools loaned from the tool crib.

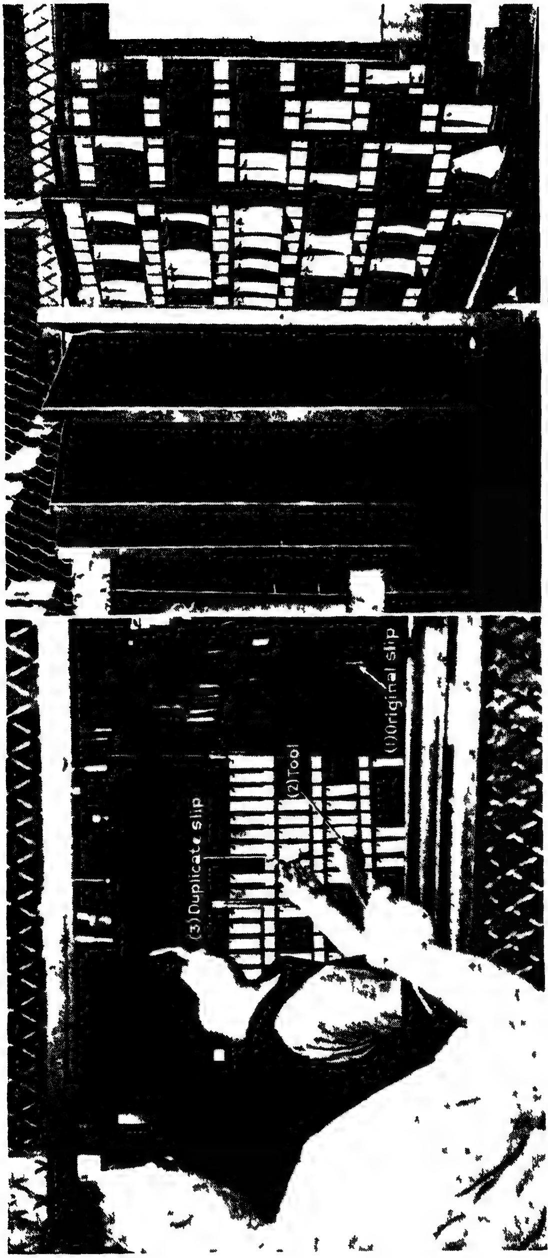
Tool-order Slips.—Under the new system, tool-order slips in duplicate are kept in dispensers at both sides of each tool-crib window. They are obtained, one pair at a time, by passing a finger under the bottom of the container, Fig. 89. The top slip is carbon-backed so that writing in pencil on the first slip is reproduced on the second.

A date stamp is available for stamping both slips. If the tool crib keeper has time, he dates the slips before placing them in the dispenser. The tool-crib keeper hangs the original slip on a hook at the tool-storage rack and then hands the tool to the workman. At his convenience, he hangs the duplicate slip on a hook assigned to the workman on a rack near the crib window, Fig. 90. These slips show what tools each man has drawn from the crib. In the larger cribs these hook racks are arranged in "books."

When a tool is returned, the duplicate slip covering that tool on the man's hook is removed by tearing through the punched hole. The torn slip is shown to the workman to indicate that he has received credit for returning the tool; then it is kept with the tool until it is returned to the storage space, regrind tray, or scrap box. The original slip is removed from the storage-space hook. Tools broken or worn out are so noted on the torn order slip, which then is placed in a "replace" container for information of the man who must reorder them.

Borrowing Tools.—For borrowing tools from other departments, each tool crib has a limited number of brass tool-crib checks serially numbered on one side and marked with the tool-crib number on the other. For each tool-crib check there is a brass slip of the same serial number. The use of a distinctively marked brass tool-crib check is a precaution to prevent unauthorized borrowing from tool cribs of other departments.

When a required tool is not available in the home crib, both tool-order slips are marked with the number of the home crib and a tool-crib check serial number. The original slip then is placed on the hook from which the correspondingly numbered brass slip and tool crib check have been removed. The tool-crib check is handed to the man, and the brass slip is hung on his hook.



A B

FIG 90.—*A* Tool crib attendant placing duplicate tool-order slip on man s hook after placing original slip on tool hook and handing tool to workman *B*. Hinged name and pay-number hook racks arranged in book form in toolroom

If a messenger is sent for the tool, the man retains his original slip until the tool is delivered to him.

The workman, or messenger, hands the duplicate tool-order slip and the brass tool-crib check to the keeper of the lending crib in return for the tool. The brass check is hung on the hook at the tool storage space, and the slip is placed on a hook labeled "Other Crib Loans."

The man can return the tool to his home crib or to the crib from which it was obtained. In the former case, the brass slip is removed from the man's hook and returned to its original hook, from which the original tool-order slip is torn. This slip is kept with the tool for identification. Upon receipt of the tool by the lending crib, the duplicate slip is torn from its hook on the rack, and the tool-crib check is returned to the borrowing crib. In case the workman returns the tool direct to the lending crib, the above procedure is reversed, and the workman returns the check to his home crib instead of the tool. This clears him of responsibility for the tool.

This tool-crib system has the following advantages: (1) It shows immediately who has a given tool and how long he has had it; (2) it shows all the tools for which a given workman is responsible; (3) it reduces time spent by workmen at tool-crib windows; and (4) it eliminates unnecessary filing of slips.

All the foregoing relates to tools borrowed to be used for a relatively short time. Tools that a workman retains for a long time are charged to him on a loan card. This notation is transferred to a record card in a central file for the entire works. The central-file record of tools eliminates repeated thumbing over of slips.

When a workman leaves the employ of this works, he first clears his account at his home crib. This, of course, means that he must have returned all borrowed tools to other cribs. Then he returns to the central file the tools charged to him there.

TOOL TICKETS VS. BRASS CHECKS

Many who have abandoned brass checks in favor of tool tickets and have used them long enough really to compare results find the tool tickets better in every way. For example, a nationally known manufacturer with 15 tool cribs recently made a 24-hour time study of tool service in a crib equipped with the McCaskey

"ticket" system and others using brass checks. The time required per transaction with the brass-check system averaged 1.24 min., whereas the ticket system required 20 sec., or an approximate ratio of 4 to 1. Their workmen draw from one to twelve tools with an average of two and one-tenth tools per trip.

Advantages of the Ticket System.—The same organization found, after two years' experience, that they had reduced their tool inventory in the McCaskey-equipped crib approximately \$9000 and had reduced their breakage from \$90 to \$40 per month; that tools "lost, strayed, or stolen," frequent with the brass-check system, were very rare with the McCaskey system; that their workmen and crib attendants would rebel at going back to the brass-check method because arguments over missing tools had been entirely eliminated and tool service had been speeded up; that the time required for annual physical inventories had been reduced from 338 man-hours to 104 man-hours. Facts have convinced that the ticket method is preferable.

Filing Equipment for the Ticket System.—The speed and efficiency of the system is dependent on the method of cross filing the tickets and by-product records that provide the basis for inventory and breakage reduction. Makeshift filing equipment will not do the job, but specially designed visible filing equipment is available. If it is used, no workman can draw more tools than the management wants him to have, and he cannot hold out pet tools indefinitely, as is possible with brass-check systems.

EFFICIENT TOOL STORAGE

Tool storage is an actual problem, especially where a large quantity of drills, cutters, and the like are involved. It is equally important to have a place for such materials as drill rods and other small stock frequently needed either in making tools or in the product being manufactured.

Methods of storage vary widely from bins or boxes, in which tools are dumped with little regard for the cutting edges, to modern racks with more or less refinement as to both appearance and protection of the tools themselves.

Example of Toolroom Equipment.—One of the most interesting installations of toolroom equipment is in a large plant which prefers to be nameless but which has afforded the opportunity of illustrating some details of a typical tool crib.

The racks shown are of steel, as is all its tool-crib equipment. They are of substantial, welded construction, with the unusual feature of being mounted on six double-wheel casters. These make it possible and practical to move the racks for cleaning the floor and to rearrange them as changes become necessary.

A general view, Fig. 91, shows three double racks. They are painted white, kept clean of dust by vacuum, and are repainted when necessary. Racks that hold keen-edge tools that might be easily damaged have a wooden lining to prevent dulling. Figure 92 shows racks for drills and reamers. A similar rack

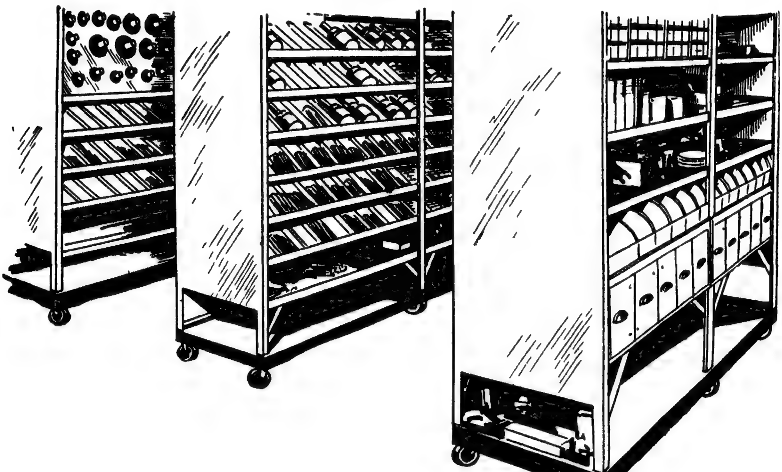


FIG. 91.—Steel racks mounted on six double-wheel casters are readily movable.

with wooden pegs is used for milling cutters. Heavy milling cutters are kept at the bottom of the rack and such equipment as screw jacks and tool-post grinders are stored as in Fig. 92. There is a special rack for collets used on different machines.

Supplies, such as drill rods, small pieces of steel, and similar stock, are kept at the top of a rack. Below the steel is the rack for files, some of which remain in the original boxes until called for. Each compartment bears a number, which is a great help in selecting the files wanted.

Outside the tool crib is a file sample board, with each file, numbered as well as named. The man who wants a file studies

this sample board, finds the number of the file he needs, and relays the information to the toolroom attendant. It is an easy matter for him to pick out the file, or files, wanted, and there is no time wasted because of using different names for the same file or any other reason.

Rack for Micrometers.—Micrometers are expensive tools, and care in storing them is absolutely necessary. Many micrometer racks hold the instruments vertically, some holding them on

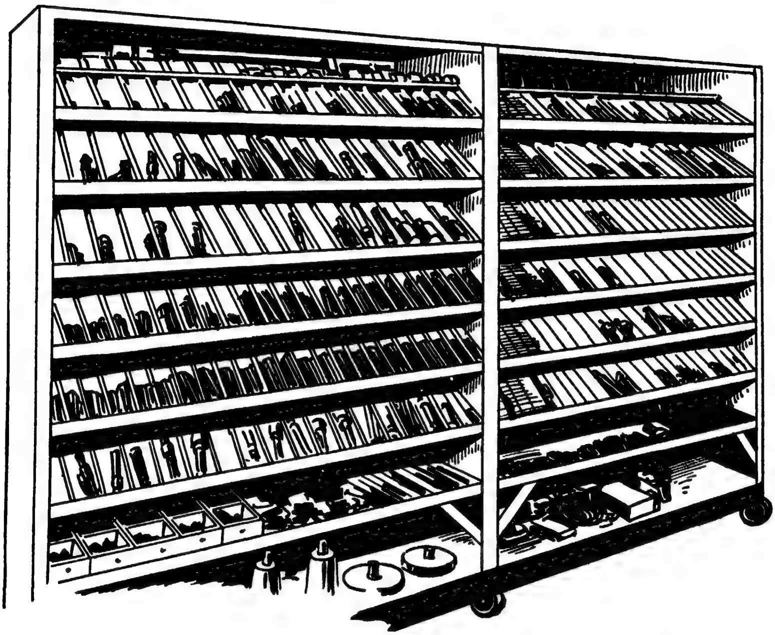


Fig. 92. Drills and reamers lie in inclined, wood-lined compartments.

their back, and others hanging them at different points on the frame. The storage method employed here has a compartment where each micrometer rests on its side with the measuring points outside the rack.

Beneath each opening is a number designating the capacity of the micrometer. The checks are hung on hooks at the extreme upper left, where the numbers correspond with those under the micrometers. Standard 1-in. micrometers are supplied by the men themselves. These are inspected for accuracy periodically in the tool-inspection room.

MAKING THE TOOL CRIB PAY[1]

Sometimes we think of a tool crib as a necessary evil. This is as erroneous as the idea that production control and budgeting are a waste of time. A tool crib is really a productive unit; the attendant performs a productive function when he makes tools available to the workmen with the least possible delay. It reduces lost productive hours and controls tool inventory.

A good tool-crib system must satisfy the following requirements: (1) Service must be rapid for productive workers; (2) tool inventory must be held at a minimum; (3) expenses caused by tool breakage and loss must be held at a minimum; (4) records must be accurate, simple and complete; (5) responsibility for tools removed from the crib and for tools damaged must be placed on an individual workman or supervisor; (6) tools must be inspected and repaired upon return to the crib; (7) two or more tool cribs must be interlocked into an integrated system; and (8) repair of tools must be performed in an economical manner.

First, full responsibility must be placed in one man; it is not economical to permit separate departments to operate their own tool cribs. It sometimes is said that each department knows best what tools it needs and how to maintain them properly. In theory this is true, but it seldom works out well in practice. Many plants that operate with separately controlled tool cribs admit that the tool-control system in use is the weak link in their plant.

Tool-crib Accounting.—To be efficient, a tool crib must have a modern method of accounting for all tools for which the crib is responsible. To some this may seem expensive, but industry does not hesitate to institute modern accounting methods in all other parts of the business; it has been found to pay well. The same is true of the tool crib. There have been many methods based on variations of the brass-check system; all of these have, more or less, failed to give an accounting of tool loss, breakage, turnover, inventory, and loss of productive time at the tool-crib window.

[1] By John A. Bissinger, Jr., superintendent, machine shop, engineering works division, Dravo Corporation.

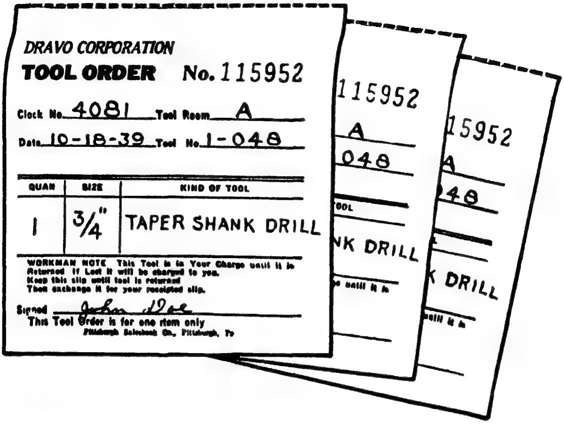
To account for tools properly, it is necessary to (1) have a complete record of each transaction at the window; (2) account for lost or broken tools; (3) know repair costs immediately; (4) be able to show tool turnover; (5) provide a record of tool breakage and lost tools for the foreman of each department; (6) identify certain types of tools by serial numbers in order to avoid one workman's turning in tools assigned to another; (7) classify tools under a simple number system; (8) be able to make a quick and thorough inventory of tools.

Fig. 93.—At the tool crib.

To follow through the above, step by step, there is only one answer: that is a paper record. The common reaction to a suggestion for additional paper records is that we already have too many reports to fill out now. That may be true, but it is not true if the correct system is in use.

Under the tool-control plan now in effect in the engineering works division of the Dravo Corporation, the workman, when he requests a tool at the crib's service window, sets in motion a series of steps in the tool accounting system (see Fig. 93). First, he makes out a tool-request form in triplicate, as shown in Fig. 94. The tool classification number is added by the tool attendant

when the requisition is presented at the crib. The original copy then is filed in a rack under the workman's check number or


DRAVO CORPORATION
TOOL ORDER No. 115952
Clock No. 4081 Tool Room A
Date 10-18-39 Tool No. 1-048

QUAN	SIZE	KIND OF TOOL
1	3/4"	TAPER SHANK DRILL

WORKMAN NOTE This Tool is in Your Charge until it is Returned. If Lost it will be charged to you. Keep this slip until tool is returned Then exchange it for your receipted slip.

Signed John Doe
This Tool Order is for one item only

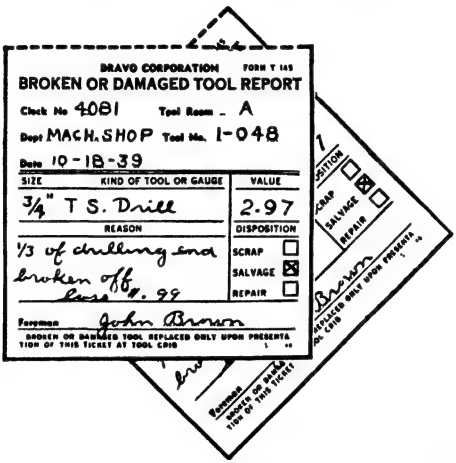
FIG. 94.—Made out in triplicate by the workman when he needs a tool, this form gives a record of who has the tool, how many times the tool is needed in a given period, and fixes responsibility for misuse

FIG. 95.—Compact record rack.

name, and the second, or carbon copy, is filed in a similar rack under a clip identified by the tool number, Fig. 95. The third

copy is given to the workman as his record of the transaction. When the tool is returned, the workman brings with him his copy of the requisition, which helps the attendant in finding and removing the first two slips from the files. The original copy then is returned to the workman if the tool is found to be in good condition.

When the tool returned by the workman is in poor condition, showing evidence of misuse, his record is not cleared until he returns a defective- or damaged-tool report, Fig. 96, signed by his foreman. On this form is entered the replacement price if


BRAVO CORPORATION FORM T 145
BROKEN OR DAMAGED TOOL REPORT
Clock No 4081 Tool Room - A
Dept MACH. SHOP Tool No. 1-048
Date 10-18-39

SIZE KIND OF TOOL OR GAUGE	VALUE
3/4" T S. Drill	2.97
REASON	DISPOSITION
1/3 of drilling end broken off Loss #. 99	SCRAP ☐ SALVAGE ☒ REPAIR ☐

Foreman John Brown
BROKEN OR DAMAGED TOOL REPLACED ONLY UPON PRESENTATION OF THIS TICKET AT TOOL CRIB

FIG. 96.—When a tool is damaged, the workman's record is not cleared until his foreman has signed one of these reports.

the tool cannot be redeemed or the repair cost if it can be salvaged. A workman is not delayed if his foreman is not available, but another tool is issued to him, on another tool requisition. Then the foreman signs the damaged-tool report later.

Tool-turnover Report.—In order to record the turnover of tools, the second copy of the tool-request form is made use of. After the workman returns the tools to the crib, the second copy of the original requisition is filed in the back section of the rack. These dead slips are counted and recorded at the end of the month to show the turnover of each type of tool. At the end of several months the tool-turnover report, Fig. 97, shows distinctly the items that have little use and can be removed from the crib. A foreman will hesitate to order extra tools when confronted with

evidence on the tool-turnover report that these tools are not needed.

A record of all slips showing damaged or broken tools is recapitulated weekly in a defective-tool report, Fig. 98. A copy of this report is turned over to the superintendent or foreman

T-156

DRAVO CORPORATION

MONTHLY TOOL TURNOVER REPORT--1938

Toolroom A

Tool No.	Description	Quan.	Value	Jan.	Feb	Mar	Apr.	May	Jun	Jul.	Aug	Sept.	Oct.	Nov.	Dec.
1-042	21/32 TS. DRILL			5	11	6	6	8	2	4	1	2	4	3	
-043	43/64 " "			1	1	2		1			1		1		
-044	11/16 " "			38	10	9	17	13	2	6	11	25	16	16	
-045	45/64 " "			1						2			2		
-046	23/32 " "			4	2		6	3	1	1	1	3	6	2	
-047	47/64 " "			1		2	3	3		1		3	5		
-048	3/4 " "			14	9	10	14	15	7	3	4	10	18	14	

FIG. 97.—This form shows how often tools are used.

of each department, another copy is kept in the tool supervisor's file, and a third copy is sent to the works manager. The individual supervisors make a definite effort to reduce their tool loss and breakage account when provided with these weekly reports. They soon catch the repeaters, especially since the tool breakage

T-150

DRAVO CORPORATION

Weekly Defective Tool Report

From OCT 23 To OCT. 30, 1939 INCLUSIVE

Tool Room A

Tool Number	Description of Tool	Check Number	Workman's Name	Dept.	Nature of Defect	Cost of New Tool or Repair
1-026	13/32" TS DRILL	1804	J DAUGHERTY	ELECT.	BROKEN-RECLAIM 3/4 LENGTH	0.25
128-011	5/16" BOLT TAP	1830	C SHIREY	"	BROKEN-SCRAP	0.57
90-015	SLEDGE	3011	J BATTISTO	STRUCT	BROKEN HANDLE-36 IN.	0.53
98-010	WELD GLASSES	3039	R PALAZZINI	"	BROKEN LENSE	1.55
98-001	GOGGLES	3111	S. SUDIA	"	REPLACE HEAD BAND	0 20
90-026	WELD HAMMER	3188	S GALBA	"	WORN OUT	1 16
2-022	11/32" SS DRILL	3095	S. BURAN	"	BROKEN-SCRAP	0 56
					TOTAL FOR WEEK	$ 4.82

FIG. 98.—Weekly report of tool damage.

is charged to the individual department's overhead. In one case, tool breakage was reduced to 25 per cent of the former value within a short time after the reports were inaugurated.

Certain types of tools must be identified, or workmen will attempt to turn in tools assigned to another workman. Such

tools are marked with serial numbers, so that if a man turns in a tool not assigned to him, it is kept and the man to whom it originally was assigned is notified. The offender is required to find and turn in the tool issued to him. It is often surprising how quickly they can do this. It requires only a few months of operation of the tool accounting system to show which tools should be given identifying numbers.

Classification of Tools.—The heart of a good tool system is the classification of all tools. This should be simple and easily explained to the tool crib attendant. The Dravo Corporation prefers a classification system using numbers only and has set up a variation of the standard decimal system arranged to cover every type of tool in use in the plant. By this system it is easy to identify any variety of tools; to date, only 150 series of the 1000 available have been used, leaving 850 series available for future use on jigs and fixtures.

The system takes care of drills, wrenches, measuring instruments, taps, thread gages, jigs and fixtures, portable tools, and many others. Miscellaneous tools of which there are only one or two in the plant are easily classified under one number. The six-digit form of classification is used, of which the first three digits give the series into which the tool is classified, and the second three digits represent the size, type or tool serial number.

For instance, a $1\frac{1}{4}$-in. Morse taper-shank twist drill carries the number 001-080. The 001 digits indicate all high-speed two-fluted twist drills, and the 080 digits represent the size in $\frac{1}{64}$ in. Thus 080 represents $\frac{80}{64}$ or $1\frac{1}{4}$ in. A 1 in. diameter drill would be indicated as 001-064. Miscellaneous items are numbered arbitrarily.

Portable tools are classified by using the first three digits to indicate the type of tool and the second set of three digits to indicate the serial number of the tool itself. For instance, series 124-000 is assigned to pneumatic riveting hammers of all sizes; series 125-000 identifies pneumatic air drills and reamers; series 127-000 refers to burning torches and hose outfits; and series 154-000 is assigned to small electric hand drills. They give a plant number to all portable tools in order to trace and identify them readily, rather than use manufacturers' serial numbers which would require using the name and model of the machine in order to identify it. Thus the number 124-006 on a tool-

requisition slip indicates that the tool in question is a pneumatic riveting hammer carrying the plant number 6.

Since different workmen receive their training in different industries and in scattered parts of the country, the workmen often will identify a tool by several different names, and will use various spellings and abbreviations for each name. The tool-crib attendant identifies the tool by its serial number which automatically places it in its proper class. This requisition system will not function to produce the best results unless the tool can be identified accurately by some other means than the name assigned to it by the shop workman.

The tool-control system outlined is readily applicable to 1 or 100 tool cribs, because it has as its base a complete record of each transaction. The use of the classification system ensures proper records in any number of cribs. Tools that are slow-moving in one crib can be transferred to another crib where they are used more frequently. Reports show where there is a surplus of tools and whether additional tools of a given type should be purchased. By interlocking control of the tool cribs with the paper system, repair-work charges are easily distributed, and costs for new tools and tool repairs and records of tool life are assembled easily.

Tool Turnover.—It is easy to note tool turnover since at the end of each period, all filed slips can be counted rapidly to give a tool turnover for that period. A tool attendant who handles 200 to 300 men from his crib window can take his turnover record in about two hours. The turnover record for each size and type of tool is recorded on the monthly tabulated tool turnover report. This is used as a basis for ordering new tools, and if it is cheaper to buy certain tools in quantities, the most economical quantities are quickly estimated.

When the tool turnover is known, the layout of tool bins for the most efficient handling of tools can be planned. Thus the tool attendant is saved many steps, his service is speeded up, and he is available for many small repair jobs. The drill and tap bins are divided, the ones most often used are placed near the window and the others a corresponding distance away. It is also easy to predict the use of tools in the productive cycle. For certain jobs, therefore, certain tools are moved nearer the window. When the men cease to use this type of tool, it may be

stored on the mezzanine in some toolrooms or in bins farther away from the tool window.

Under the present system workmen are not so careless in their use of tools. Tool breakage on portable tools has dropped to about 25 per cent of that under the brass-check system. Previously, if a man took out a tool and returned it immediately, saying it was defective or, in the case of portable power tools, that it was not functioning, there was no record of who had had it out last, except the memory of the tool attendant, which is not always reliable. Under the present system, it is possible to refer back to the last man using this tool and charge the repairs against him. This has eliminated most of the trouble caused by turning in defective tools with no report to the tool attendant by the user.

Time Saving.—Under the brass-check system it was possible for one crib attendant to handle approximately 60 transactions per hour, and he was kept extremely busy. With the tool-requisition system, as many as 125 transactions per hour per man without difficulty are possible. This figure is based on time studies. The saving is the direct result of the speed with which a transaction is completed, especially in the return of the tool to the crib by the user. There is no delay. A quick-check inspection, maybe a question to the user, and the original slip can be removed quickly from the rack and returned to the workman. Removal of the slip from the active-tool record file to complete the transaction can be done later. Eighty to ninety transactions an hour are all a tool attendant can handle efficiently during the early and latter parts of the day. During most of the day he will handle 40 to 60 transactions per hour.

It might be supposed that men who speak broken English or cannot write English would cause excessive delay. This should be especially true where a large foreign element is employed. There is little trouble caused by this, however, since the few who cannot write are usually on jobs requiring few tools and the others apparently do not slow down the speed of operation of the system. In the Dravo Corporation the foreign group is large but has presented no particular problem in the operation of the system.

It takes 2 hr. at the end of each month to record tool turnover in a crib serving 200 to 300 men, as in Fig. 99.

Under the present system the tool-crib attendants are used for more repair work than formerly, and other departments have even turned over minor repair jobs that occur frequently. With the speed of the requisition system, a tool attendant is available for a considerably greater period of time to sharpen drills, make simple repairs on portable power tools, repair burning equipment, paint-spray equipment, disinfect and repair respirators, goggles, and welding helmets. They also repair hammer handles, dress striking tools, and grease portable pneumatic tools.

FIG. 99.—Tool turnover is recorded at the end of the month

Before the tool requisition plan was installed, it was costing this company an average of $1200 a month for one tool crib, the first placed under the tool-requisition system. A gradual reduction in operating costs was begun until it reached about $700 a month, at the same time the service was stepped up and a greater number of tools made available. Other savings include cost reductions in tool breakage and loss, reduced inventory, and the introduction of a thorough inspection.

NO LOCKS ON THIS TOOL CRIB

For ten years a Midwestern tool plant has used a tool crib with no attendant, no fence around it, no check system, and with

free access permitted to all. Visitors have pooh-poohed the idea, but the simple fact is that no case has been uncovered where anything has been stolen.

This tool crib is a rectangular wooden structure in the center of the shop, and the storage bins face inward. Access to the crib is obtained by openings cut in diagonal corners. The walls are only shoulder high. Freely exposed on the shelves are grinding wheels, nuts and bolts, lubricants, and many other items that men could use in their own workshops or on automobiles.

Two complete sets of micrometers are set right out in the shop. One set is in the grinding department and the other in the lathe department. These tools range from 1 to 24 in., but never has a micrometer been stolen. In fact, one day a worker reported that his own micrometer had been stolen and a watch was set. Nothing happened until the janitor asked the foreman what the piece was he had found in the boiler clinkers. The toolmaker had carelessly allowed his micrometer to fall into a trash barrel.

One of the reasons why this shop keeps its personal and moral relations on a high plane is that 40 per cent of the force are related in some way. Newcomers are usually spoken for by an employee. If the new man does things out of tradition, he is soon set right by his fellows. Honesty and cleanliness among the men can be traced to the way the employer runs his shop—he expects honesty without saying so. He also sees that the entire shop and the washrooms are kept clean all the time.

A LARGE TOOLROOM

The layout of a large toolroom in a very progressive plant is seen in Fig. 100. This toolroom is in the plant of International Business Machines Corp., Endicott, N.Y. In addition to making new tools, this toolroom takes care of tool maintenance and tool changes. These changes may be necessary because of some weakness in the tool or because of an improvement that may have been developed by its use.

When tools are returned to the tool crib, they bear either a green or a red slip which has been attached by the foreman of the department from which it comes. The green slip indicates that the tool is O.K. to go out again, but the red slip shows that it needs repairs. Any tool with a red slip goes to tool inspection at once.

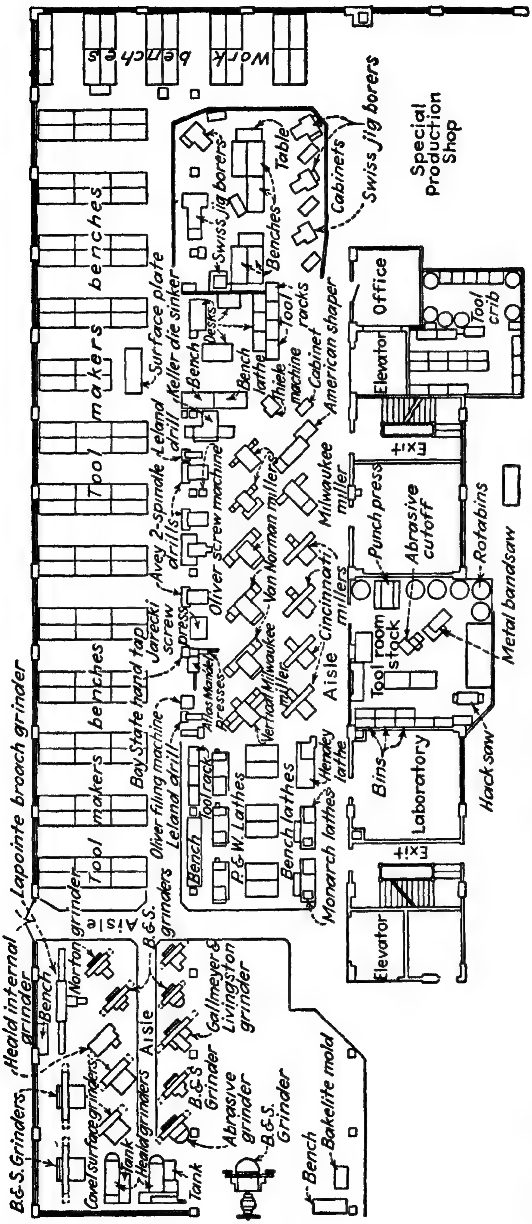


FIG. 100.—Grouping machines according to operation together with convenient bench arrangement is a feature of the toolroom layout.

Each toolmaker has his own toolbox with a complete set of measuring equipment. Both the box and the tools may be bought from the company at cost. In addition, each toolmaker has a set of drills, reamers, counterbores, and taps that are kept at his bench in a locked drawer.

The toolroom carries from 7 to 10 tons of steel in stock, all marked in color code to ensure the selection of the right steel for each job.

The layout of machines and benches is worth careful study. It will be noted that all the benches run at right angles to the wall with the windows. The machines are all indicated so one can see just what was selected in making up the equipment of this department. This layout would make an excellent guide in determining the layout for medium or large toolrooms.

CARE OF TOOLS

Large-scale Tool Grinding.—The Packard Motor Car Company has a centralized tool and cutter grinding department laid out to concentrate similar operations and expedite flow of work. During the production season, this department must recondition about 2600 tools a day on a three-shift basis. By bringing scattered facilities together under one head, better and faster service is rendered to the producing divisions.

Dull tools of all kinds are trucked to the grinding room in boxes bearing production-department symbols. Small tools are unloaded at the receiving bench, which is divided into sections for the respective departments. Squad leaders route small tools to the appropriate machine sections for reconditioning and see that they are brought back for inspection. Large broaches and cutters are trucked directly into the proper resharpening sections to avoid extra handling.

In section *A*, on the floor plan, Fig. 101, inserted-blade tools, except those ganged on arbors, are placed on benches for resetting blades and for replacing broken blades or blades too short for further grinding. Tools are reground in universal-grinder section *G*, backed off in section *M*, and sent to inspection.

In section *B*, arbors with ganged cutters are disassembled on a bench and the cutters sent to the universal-grinder department, next to the backing-off section, then returned to section *B* for assembly, and finally sent to inspection. Side cutting edges of

inserted blades in ganged cutters must be parallel to the arbor-boss face and at right angles with the arbor hole to maintain accuracy in production. While being ground, each cutter is held on an annular ring with the sides ground accurately parallel.

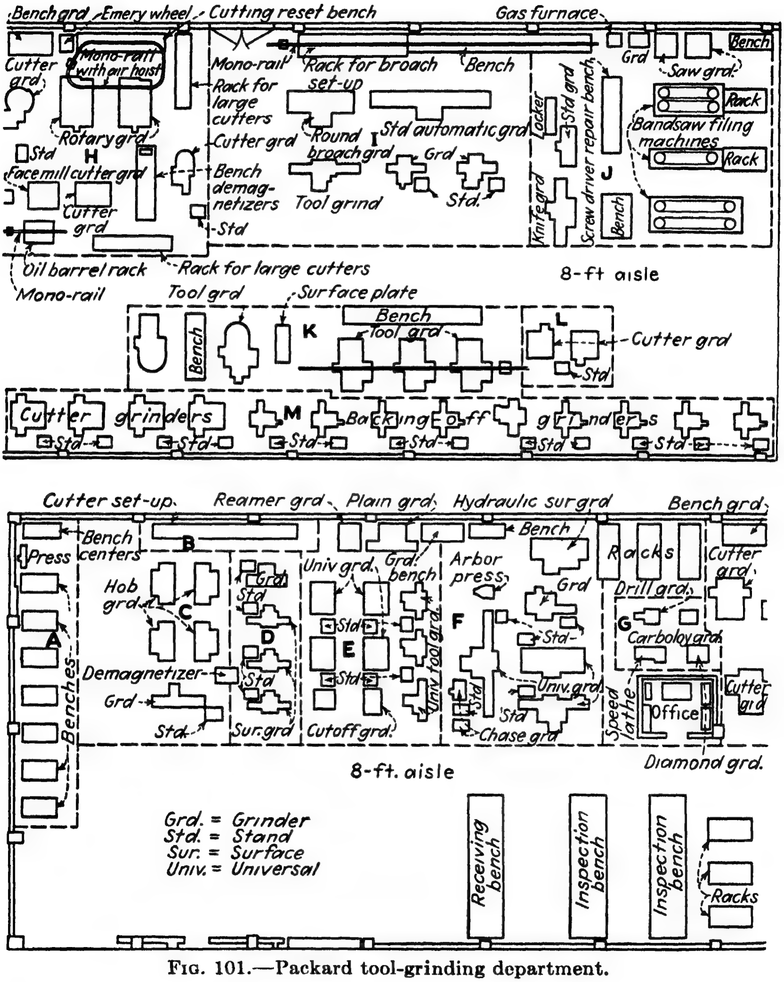


FIG. 101.—Packard tool-grinding department.

A clamping bolt passes up through the center of the ring and through the arbor hole in the cutter.

All hobs used in the plant are ground on four Barber-Colman hob grinders in section *C*. Four Brown and Sharpe surface

grinders in section *D* sharpen single-point tools, form tools, and inserted cutters.

Threading the tools and miscellaneous work are handled in section *E*.

In section *F*, four Brown and Sharpe universal grinders are used for miscellaneous work. Two machines are set up for expansion reamers and general external work, a third for internal work, and the fourth for cemented-carbide tools exclusively.

Cemented-carbide single-point tools and drills are reconditioned in section *G* on a Carboloy grinder, an Ex-Cell-O diamond wheel grinder, a drill grinder, and a speed lathe.

All Ingersoll cutters for blocks, cylinder heads, flywheel housings, and manifolds are ground in section *H*. These large cutters are delivered direct to a rack with vertical wood partitions. A monorail and air hoist are used to lift cutters onto a bench for resetting or replacing blades; next to either of two Heald rotary surface grinders; and thence to a demagnetizer. Cutters are then placed on the Ingersoll cutter grinders and finally sent to inspection.

Broaches and Saws.—Broaches, both flat and round, are sharpened in section *I*. A chain hoist lifts heavy broach holders onto a bench for disassembly. The flat broach itself is sharpened on a large Thompson surface grinder. If necessary, flat broaches are recut on two revamped Oakley grinders equipped with vertical Ex-Cell-O spindles. Round broaches are reconditioned on a Colonial or Brown and Sharpe grinder.

Bandsaws and circular saws are sharpened in section *J*. Circular saws are reground on two automatic machines. In section *K*, high-speed steel, single-point tools are reground on two Lumsden and three Tabor grinders. The former, being faster, are used solely for crankshaft and camshaft turning tools. The Tabor machines regrind tools used for turning gear blanks, axle shafts, cross-arm shafts, and work of similar nature.

In section *L*, about 85 Fellows gear-shaper cutters are ground in three shifts.

All backing-off work is segregated from the rest of the grinding room, in section *M*. Since the work is done dry it is desirable to keep this work to itself because the exhaust connections can be laid out more efficiently and any escaping dust is not thrown into other machines.

Each of the 48 grinders on which the work is ground dry has an exhaust hood with a 3-in. orifice. Air velocity through the orifice is 9000 ft. per minute, which is equivalent to a suction of 5 in. of water. Exhaust ducts are connected to a 38-in. main duct, which handles 38,000 cu. ft. of air per minute.

A 200-ft. power duct running down the center of the department provides quick connections for machines and permits easy rearrangement. Flexible cable from the machine is looped from the ceiling and connected with the power duct through a fused plug.

Keeping Tools Sharp.—Cutting edges determine the efficiency of the machine tool. Sharp tools with proper cutting and clearance angles make it possible to secure maximum results in machining. Drills improperly ground and milling cutters that are dull or do not run true handicap the performance of the best machines. Dull taps not only delay production but are much more likely to break in the holes and so cause endless trouble. Dull taps and reamers also fail to give the size holes we expect and mean added work in assembling parts. In short, dull tools cost money.

Few realize the extent to which dull and improperly ground tools add to the cost of production. Extensive studies of tool conditions show these losses very clearly and how they can be prevented. The remedies suggested by the very practical engineer making these surveys can be followed in almost any shop. Some of his observations and suggestions follow; they are divided into sections dealing with different tools and are made concise so as to be more easily consulted and followed.

Drill Shanks.—Many taper shanks of drills are battered and scored. This prevents proper fit in the drill-press spindle or sleeve. Drills run out and fail to drive properly, resulting in broken tangs. Poorly fitting shanks should be trued if necessary whenever the drills go back to the tool crib.

Drill Points.—Only sharp drills with proper point angles can do the best and most efficient work. Hand-sharpened drills are seldom most efficient. Machine grinding can give better cutting edges than can be done by hand and with less waste of drill material. In some of the shops studied, machine sharpening has increased the life of drills 100 per cent.

Cutting edges are often "burnt" or softened in hand grinding. Hardness is reduced from 5 to 15 Rockwell points, which greatly reduces the amount of work and the life of the drill.

Proper cutting and clearance angles cannot be maintained by hand grinding. Only a good drill-grinding machine can secure the most efficient angles for maximum production.

Web thickness should be carefully watched. Webs are made thicker toward the shank to increase drill strength. Web-thinning machines are available and should be used to maintain efficiency as the drill points are ground back. Thick webs take more power and reduce chip room. This tends to heat the drill and to break it. In one shop the web thickness varied from $\frac{1}{16}$ to $\frac{9}{64}$ in. at the point for the same size drill.

Drill-point, or lip, angles should vary with the material to be drilled. Although 118 deg. included angle is considered a standard for average work, many operators find an angle of 124 to 137 deg. best in their work. Clearance angles vary from 4 to 17 deg.

Operators who sharpen drills should be provided with gages so that point and clearance angles, thickness of web, and concentricity of the drills can be maintained.

For drilling so-called "ebony" or other materials of an abrasive nature, drills are made with what is known as a "high-speed case." These materials and also plastics are hard on drills. They wear the lands, or margins, which determine the size of the hole.

It saves time to have a supply of sharpened drills near the machine on which they are used. It increases production to have them sharpened properly for the work to be done. This can seldom be done by hand either on the job or in the toolroom. Even where it takes longer to use a machine for sharpening, it pays in increased life of the drill and in greater production. Drills should be ground in the toolroom to the angles found best for different work.

Taps.—Taps should be stored so that cutting edges do not contact, and the same is true of reamers. Taps may be stored vertically by their shanks or in separate compartments, as should reamers. Sharpening should be done by a tap grinder in the toolroom. Several good tap grinders are available.

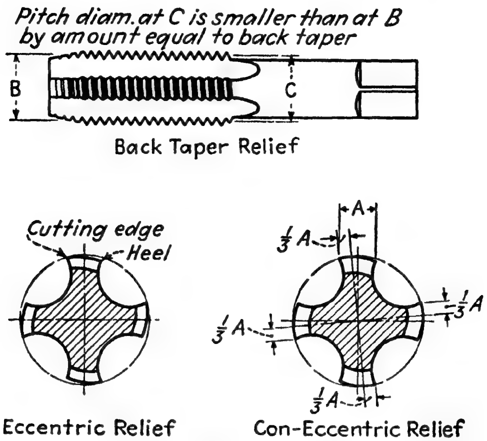


Fig. 102.– Terms used by tap makers and users

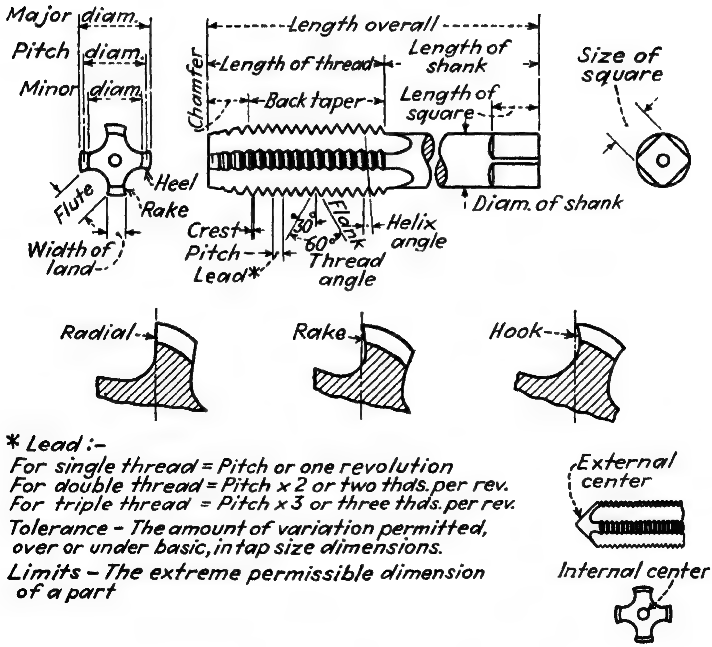


Fig. 103.—Suggestions on grinding taps.

Taps should be carefully selected to suit the work they are to do. Two of the important features are the kind of relief and the angle of hook of the tooth face. A typical tap and two kinds of relief are seen in Fig. 102

TABLE 4.—TAPPING LUBRICANTS RECOMMENDED

Material	Lubricant
Cast iron	Dry; or kerosene-paraffin
Brass	
Soft	Soluble oil or light paraffin
Hard	Soluble oil or light paraffin
Rod	Soluble oil or light paraffin
Bronze	
Manganese	Light paraffin
Regular	Light paraffin-kerosene
Copper	
Die casting aluminum, zinc	Kerosene and lard oil
Duralumin	Soluble oil or kerosene
Fiber	Dry
Rubber	Dry
Bakelite	Dry
Monel	Sulphur base—lard oil
Nickel silver	Sulphur base—lard oil
Allegheny	Sulphur base
Steel (cast)	
Low and medium carbon	Sulphur base
Chromium	Sulphur base
Manganese	Sulphur base
Molybdenum	Sulphur base
Nickel	Sulphur base
Stainless	Sulphur base
Tungsten	Sulphur base or kerosene and lard oil
Vanadium	Sulphur base or kerosene and lard oil
Machinery	Sulphur base thinned with kerosene
Malleable iron	Soluble oil

NOTE These data are general and may require further study for specific tapping conditions

With eccentric relief the tap becomes smaller with the slightest wear. But with con-eccentric relief, the tap diameter is maintained for the first third of the land. This type is particularly useful in copper and similar metals with a 20-deg. hook. Radial, rake, and hook teeth are shown in Fig. 103.

For tapping cast iron, either a radial tooth or one with 5-deg. rake is recommended. For steel, from 5- to 10-deg. rake works best.

TABLE 5.—HOOK OR RAKE RECOMMENDED FOR TAPPING VARIOUS MATERIALS

Material	Hook or Rake
Cast iron	Radial to 5-deg. rake
Brass:	
Soft	Radial
Hard	5-deg. rake
Rod—85-5-55	5-deg. rake
Bronze:	
Manganese	Radial
Phosphor	Radial
Tobin	8-deg. rake
Copper	20-deg. hook
Die casting:	
Aluminum	10-deg. hook
Zinc	10-deg. hook
Duralumin	3-deg. rake
Aluminum	10-deg. hook
Bakelite	3-deg. rake
Fiber	3-deg. rake
Rubber	15-deg. hook
Nickel silver (German)	20-deg. hook
Steel:	
Cast (tool steel)	5-deg. rake
Chromium	10-deg. rake
Manganese	10-deg. rake
Molybdenum	10-deg. rake
Nickel	10-deg. rake
Stainless	10-deg. rake
Tungsten	10-deg. rake
Vanadium	10-deg. rake
Machinery	5- to 10-deg. rake
Malleable iron	Radial to 5-deg. hook

NOTE: These data should be considered general and not necessarily applying to a specific tapping job engineered by the factory.

Taps should not be ground in the flute unless the original design can be maintained. As taps only cut on the chamfer at the front and up to the first full tooth, this section must be kept sharp.

Size of tap drill is important. It is not practicable to get a full thread; a 75 per cent depth is the maximum in general practice.

As with reamers, condition of the cutting edge, speed, and the kind of lubricant affect the size of the hole produced.

Taps need careful consideration, for they do a large amount of work, but above all they should be kept sharp

TABLE 6—LANDS RECOMMENDED FOR TAPS FOR BRASS AND BRONZE

No of Lands	Land Width
3	$\frac{1}{5}$ cutting edge
4	$\frac{1}{6}$ cutting edge
5	$\frac{1}{7}$ cutting edge
6	$\frac{1}{9}$ cutting edge
8	$\frac{1}{12}$ cutting edge

NOTE The foregoing data should be considered general and not necessarily applying to a specific tapping job engineered by the factory

TABLE 7—HIGH-SPEED TAPS

Material	Speed, Feet per Minute
Cast iron	70 to 80
Bakelite	60 to 70
Brass	90 to 100
Bronze	50 to 65
Bronze-manganese	30 to 40
Copper	90 to 100
Die-cast aluminum	55 to 65
Die casting—zinc	60 to 70
Aluminum	90 to 100
Fiber	80 to 90
Rubber (hard)	80 to 90
Nickel silver (German)	70 to 80
Monel metal	25 to 30
Malleable iron	30 to 60
Allegheny metal	15 to 25
Steel	
Machinery	50 to 60
Cast (low-medium carbon)	45 to 65
Stainless	15 to 25
Molybdenum	20 to 30
Nickel	25 to 35
Tungsten	20 to 30
Vanadium	25 to 35
Chromium	20 to 30
Tool steel	25 to 35

Reamers—Greater care of reamers in tool cribs will save money Many are stored with no protection to cutting edges, which become nicked and dulled When metal racks or shelves

are used, the reamers should be kept separate and protected by wood, linoleum, or other nonmetallic surfaces.

If reamers have taper shanks, the shanks should be kept free from dents or roughness. When damaged the shank should be reground the same as in the case of drills.

Reamers can only be sharpened properly in a suitable grinding machine. Only in this way can the cutting edges be kept concentric. Without this the cutting is done by only part of the teeth. Cutting edges can be easily softened by overheating in grinding.

Relief behind the cutting edge is important. Too much may cause chatter; too little may make the reamer bind in the hole. Either extreme affects the size of the hole produced. Hole size is also affected by speed and the lubricant used. The relief is best measured with a dial indicator with the reamer revolved between centers.

Reamers with helical flutes or gashes must be ground on machines with a follower that keeps the edge in proper relation to the wheel.

Milling Cutters.—Probably greater care is taken of milling cutters in tool cribs than of other tools. But still some are damaged by contact with others or by contact with metal and their life and production correspondingly decreased.

Unless cutters are carefully ground as to both concentricity and relief behind the cutting edge, their productivity will be materially decreased. Unless all teeth cut, the cutter is not doing its duty. And when the teeth that do cut are dull, all must be ground, unless the eccentricity is corrected.

Hardness of the cutting edge is very important. Overheating due to either crowding or the use of the wrong wheel may soften the edge. The following wheels are recommended:

Norton Elastic Cup Wheels

Side mills	46-I3L for roughing
	60-J3L for finishing
End mills	50-K3L
Small-end mills	60-K4L
Reamers	60-K4L
Fine-tooth saws	60-N4L
Formed cutters	36-I3L for roughing
	46-I3L for finishing
Face of teeth of end mills	60-N4L P6V

CARBORUNDUM ELASTIC CUP WHEELS

Side mills	40-9-K9C for roughing
	60-8-K8A for finishing
End mills	50-6-K6A
Small-end mills	60-6-K6A
Reamers	60-6-K6A
Fine-tooth saws	60-2-K2B
Formed cutters	36-9-K9A for roughing
	60-9-K9C for finishing
Face of teeth of end mills	60-2K2B

Relief angles vary with cutter diameter. On 1 in. diameter cutters an angle of 8 deg. is satisfactory; on $2\frac{1}{2}$ in., 4 deg.; and on 4 in., 3 deg. 40 min.

The variations shown in the relief angle are due to maintaining a radial relief of 0.003 in. on each cutter. This relief can be measured best with a dial indicator with the cutter between centers. Turning the cutter with the indicator in contact with the tooth will show the relief by the movement of the hand of the dial.

Too much relief will cause chatter, and because of insufficient support behind the cutting edge, breakdown will occur sooner than it should. A high quality of finish on the cutter teeth adds to the quality of the work produced.

In sharpening formed cutters the face angle must be maintained as originally designed. Unless this is done, the form will be changed. Cutters with helical flutes must be ground with a suitable follower. All cutting tools should be inspected after sharpening before going to the tool crib for distribution.

Causes of arbor and cutter runout are bending or bruising of the arbors, spacing collars that are not parallel on the sides, arbors too small for the hole in the cutter, or a worn bearing in the overarm support. Arbors may also be sprung by too vigorous use of a wrench on the nut at the end of the arbor.

Cutter speeds can be calculated from the surface speed in feet per minute recommended for various materials. Experience will tell when to increase or decrease speed to some extent. Feeds should be selected from the chip load per tooth. The chart in Fig. 104 will assist in this.

Form and profile milling cutters should be machine-ground. The same is true of circular form tools for screw machines. The finishing wheel should be about 320 grit, for the smoother

surface adds to the quality of the work. Blanking dies will have a longer life if finish-ground with a fine-grit wheel.

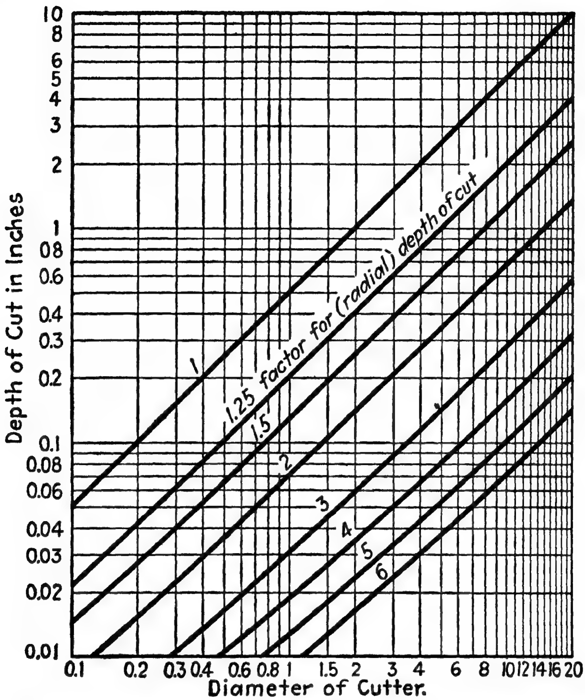
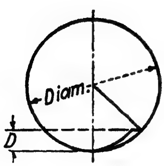


FIG. 104.—Chart for the relation of feed per tooth (F) to effective chip thickness (maximum) per tooth (T).



$$\text{Factor} = \frac{F}{T}$$

Depth of cut $= D$

Having diameter of cutter and depth of cut (radial), find the factor from the chart.

$$\text{Feed per tooth} = \text{effective chip thickness} \times \text{factor}$$

$$\text{Effective chip thickness} = \frac{\text{feed per tooth}}{\text{factor}}$$

EXAMPLE: For a 6 in. diameter cutter and 0.17 in. depth of cut, factor = 3. To obtain an effective chip thickness per tooth of 0.005, feed per tooth must be 0.005 × factor, or 0.005 × 3 = 0.015. To find the effective chip thickness if the feed is 0.012 in. per tooth, effective chip thickness = $\frac{\text{feed per tooth}}{\text{factor}} = \frac{0.012}{3} = 0.004$ in.

Many profile milling cutters have too wide a land. This requires too much relief back of the cutting edge. The primary

relief recommended is $\frac{1}{32}$ to $\frac{3}{64}$ in. on cutters under 4 in. in diameter. Cutters over 4 in. can have a relief of $\frac{3}{64}$ to $\frac{1}{16}$ in. but should have a small cylindrical land of from 0.002 to 0.004 in. Clearance back of the relief, sometimes called "secondary clearance," should provide maximum chip clearance in the flute.

While circumstances vary widely on account of material, feeds, speeds, and the condition of the machine, so that it is not practicable to predetermine exact clearances for all cutters, a few suggestions serve as a good starting point: for steel, a relief of 0.003 in.; for cast iron, 0.004 in.; for aluminum and other softer materials, 0.0045 to 0.005 in. These give good starting points, but experience may indicate that slight changes are necessary.

Countersinks.—Although not usually so important as drills, reamers, taps, and cutters, countersinks are widely used in shipyards and on other plate work. When they were sharpened by hand in one plant, the angles of 60-deg. countersinks varied from 61½ to 65 deg. All were at least 1½ deg. out.

Relief, as measured at two points on the teeth, varied from 0.013 to 0.075 in.

Eccentricity, or runout, was as high as 0.029 in., only a third of those tested being true. After making a sample fixture for holding them while being sharpened, the life was doubled and they produced 50 per cent more work.

Condition of Machine Equipment.—Not all production problems can, however, be solved by keeping cutting tools in proper condition. The machines themselves must be in good order. Loose bearings prevent both drills and milling cutters from running true and reduce the output that may be obtained. End play in either machine may also be disastrous at times. End play in drilling spindles allows the drill to break through suddenly and frequently causes breakage. It is equally injurious in milling and can easily spoil the work or the cutter, or both. The survey showed that both loose bearings and end play were more prevalent than the managements realized. With both machines and cutting tools in good order, production time and costs will be much more satisfactory to all.

TOOL MAKING BY SQUADS

The Unit.—The RCA die and mold toolrooms are organized on a unit basis. Each unit consists of two benches providing

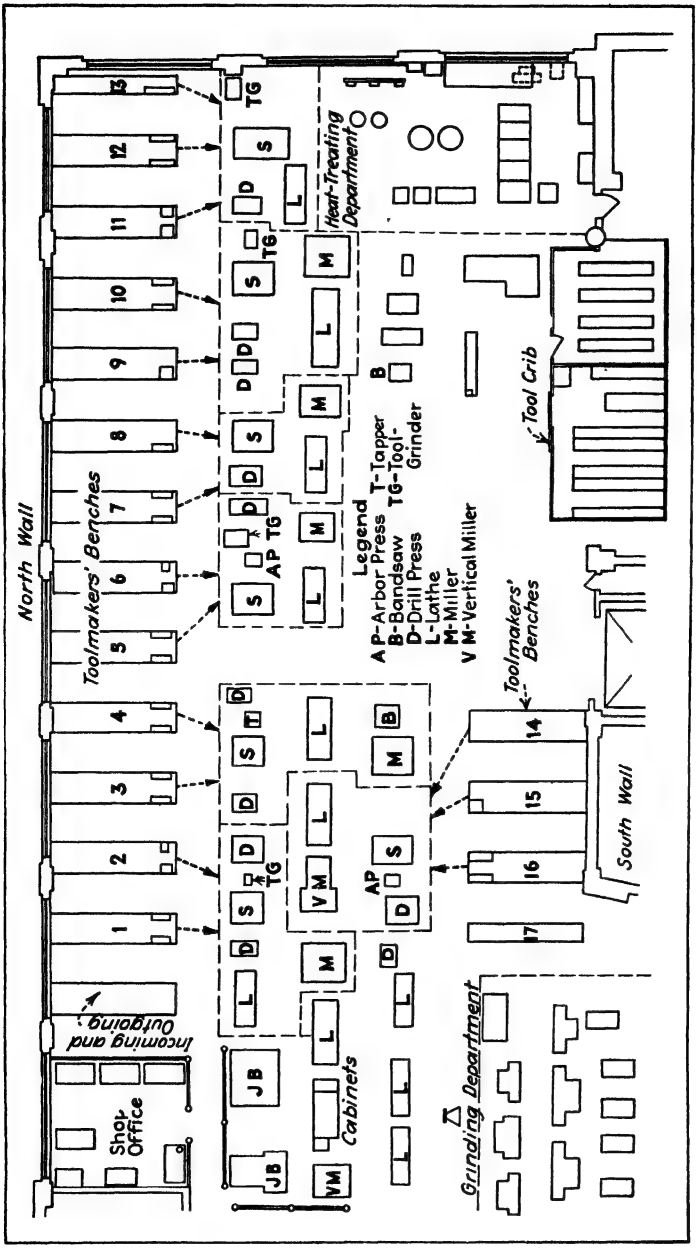


FIG. 105 —Layout of a toolroom arranged for working in squads.

working space for eight men, suitable bench equipment, a sub-tool crib and at least four different machine tools for the use of that unit only. One man of the group passes out small tools and acts as a squad leader. He reports to the subforeman, of which there are three to a floor.

The unit system removes the confusion that may creep into operation of a toolroom along conventional lines, because

1. Each group has right at hand practically all the mechanical equipment and tools that it needs.

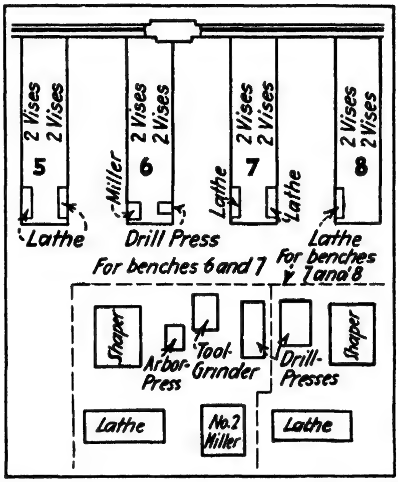


FIG. 106.—This detail from the floor plan shown in Fig. 105 shows each squad's working area.

2. Any group can specialize on certain kinds of work and be given the necessary special equipment.

3. The unit system achieves unusual neatness in the department.

4. Time is saved—the men are constantly working in a restricted area; they are not delayed at tool crib windows and supervision is easier.

As the layout, Fig. 105, shows, 13 benches are arranged at right angles to the north wall and 4 benches at right angles to the south wall. At the west end of the floor there is a segregated grinding department, and at the east end there is a heat-treating department. A detail of the working area of each squad is seen in Fig. 106.

Space for two vises is provided on each side of each bench. Thus, four men work at one bench, two facing two. Bench 1 has two bench lathes near the aisle end, whereas bench 2 has a bench lathe and a drill press. Other benches have millers or special equipment for certain classes of work. For example, bench 13 is used by men doing a large amount of special coining and swaging die work.

Two small platforms on each bench provide room for the machinists' tool kits. These platforms straddle the longitudinal dividing board, where one is used, so that the kits detract as little as possible from the working area. Moreover, the kits are arranged in rows when looking down the department. This symmetrical arrangement is conducive to orderliness but is not solely responsible for it. A visit to this shop would show that there were no objects on the floor; all work must be kept on the bench surface, and no junk can accumulate below. Thus, the sweepers have a clear road to work in during the night.

Some shops cover the benches with linoleum, some with stainless steel, while others make no effort to improve on a plain wood bench surface. At RCA the toolroom benches are covered with tempered Masonite, a pressed-wood product that comes in sheets. It is hard and smooth, permitting heavy pieces to be slid around with ease; it does not mar readily and thereby prevents splinters in the toolmakers' fingers.

Other adjuncts to the benches are individual lamps, compressed-air lines, and small aluminum chip pans placed under the bench lathes. These pans have two legs welded on the outer edge so that they can be slid under the machine until the legs abut against the edge of the bench. Thus, they are always in place.

Sub-tool Crib.—One of the greatest time savers in the reorganized toolroom is the use of a sub-tool crib with each unit. This crib is under the control of the squad boss and offers a supply of all the small tools, attachments, screws, and drill rods that his group is likely to want in the course of a day's work. It is his duty to see that the proper tools are always on hand, and he knows where the tools are. No longer is it necessary for a toolmaker to run to the main tool crib, and no longer is there a waiting line at the tool-crib window. In fact, only one attendant is now required, whereas two were needed under the old system.

A typical sub-tool crib may have collets and faceplates in the most wanted sizes, chucks, machine vises, steadyrests, all small lathe tools, T bolts, drill sets from No. 1 to No. 60, and $\frac{15}{64}$- to $\frac{1}{2}$-in. tap-drill sets, center drills, taps, tap wrenches, stripper screws and dowels, short pieces of drill rod in popular sizes, sets of reamers for dowel pins. The screws and similar material are kept in a specified number of pieces for each size and the squad leader can tell immediately how many have been used during a day's work. Thus, he is able to check against the quantity requisitioned from the main tool crib.

Machines.—Across the aisle from the benches are the groups of machines reserved for the various units. So far as possible, each unit has the following machines at its disposal: a No. 2 sensitive drill, a No. 2 power miller, a 14-in. engine lathe, a 16-in. shaper, and a double-end tool grinder. Portable equipment, such as a die filer on a rolling stand, can be wheeled into position by anyone having use for it. Screw presses for trying dies are located in the center of the shop. Thus, the means are at hand for any man of each group to carry out his work expeditiously without getting in the way of other men, walking around the shop, or waiting for someone else to release a machine.

Practically the only operations a toolmaker does not do are jig boring, grinding, and hardening. For these, it is considered best to have specialists. Moreover, segregation of grinding practically confines to one location any dust and grit that is not removed by the exhaust system.

MODEL SHOP AND PRODUCTION

Fred L. Creager of RCA tells how new ideas are quickly converted into models that are built in order to smooth out production difficulties.

Model building is a broad term. It can mean anything from "inventing" to running a large-scale department employing scores of men and utilizing modern shop facilities. The latter is a complex undertaking, and its proper functioning is vital to the manufacturing concern of which it is a part.

The function of the RCA model shop is to take drawings, sketches or oral instructions from engineers, physicists and other research men, and to convert their ideas into models that will be as nearly like the finally manufactured form as it is possible to anticipate.

Advantages accruing from this setup are:

1. Time is saved. A highly competitive business like radio requires that new ideas be rushed into manufacture or to oblivion. Delay must be minimized in building receivers; it must be further minimized by engineering the apparatus for manufacture, thereby saving in redesigning.

2. A properly coordinated apparatus is more understandable to all concerned than a crude model.

3. Fewer bugs will be discovered after the design goes to the shop.

Competent and rapid service requires adequate technical ability, management, men, equipment and a large supply of almost all conceivable materials.

An idea of how quickly the department can swing into action is shown by the building of a conventional chassis base in four hours. This is the part upon which the condensers, transformers and tubes are mounted on top while the wiring is underneath. Operations on the chassis base include piercing an average of one hundred holes, forming, welding and plating.

The work involved in the model shop includes:

1. Checking the drawings by the superintendent or his assistant to suggest any changes which will facilitate production in quantities and at the same time not affect the function of the device.

2. A breakdown of the job by expediters who route work through the model shop, accumulate stock and purchased parts.

3. Production of the chassis base and any non-standard components.

4. Purchase of required commercial items.

5. Winding coils and braiding cables.

6. Assembly of the receiver.

7. Wiring of the receiver.

8. Sending the completed job back to the engineer concerned for testing. All prints are returned with the job because ideas become obsolete quickly or because the job goes to production.

It is especially important that the model shop management have authority to suggest changes in materials or specified methods of fabrication, so long as the functional design of the apparatus is not changed in order that the completed model will incorporate current production practices. Experimental designs are worked out by technical men of different backgrounds and training. Someone with long familiarity with shop practice and with RCA methods must correlate the design with manufacture, anticipate trouble, foresee economies. Necessarily, the shop's management must keep in close touch with the factory, with new materials, new processes and with developments in communications apparatus.

Besides functioning in a consulting capacity, the shop must provide the rapid service mentioned. Its creed might be summarized as: "Find out the best way to do a job. Then standardize and forget about the detail. Don't work out the same procedure twice."

In line with the above, wherever possible, mounting dimensions of component parts have been standardized permitting the manufacture of tools with the assurance that reasonable runs may be made before obsolescence occurs.

Standard instructions for welding, plating and heat-treatment are posted at the operator's booth or station—both for the purpose of saving time and preventing mistakes. These instructions are prepared from data obtained from materials suppliers, and the authority's name is put on the sheet. Thus, any difficulties can be referred to him quickly if necessary.

In the case of a salt bath the table shows the number of minutes to obtain a certain depth of case with the proprietary material used. Heat-treating instructions for unusual materials such as beryllium copper list the temperature and time for different thicknesses and tempers. Welding data show the size of stock and corresponding current tap. Thus, operators need not bother the foreman when a little different job comes in. They cannot misunderstand verbal instructions, and they always work according to the instructions of an authority on the subject.

Speed Depends on Stock

Rapid functioning of the model shop would be impossible without an adequate supply of materials and standard manufactured parts. About 9,000 items are stocked and a perpetual inventory is kept. Bars and tubes are racked in 3 ft. lengths, sufficiently long for the small runs in the shop. These raw materials are color coded to prevent mistakes. Usable scrap is kept in the storeroom and is identified by material and temper to prevent confusion or wrongful substitution. This is necessary because electrical characteristics of different temper hardnesses of the same material are often considerable.

Resinous products are identified by purchase specification numbers and checked against specification sheets before being issued. Manufactured parts such as resistors, tubes, condensers and hundreds of other items are stored in bins or drawers.

Although a perpetual inventory is kept for all materials and most of them are bought according to usage, some unusual materials are bought in quantities when delivery conditions are particularly unfavorable. Thus, when the expediters are breaking down a job they are not confronted with delays that will prevent the model shop from getting a job out on time.

Equipment throughout the shop is of modern design and is arranged to facilitate production. The men are high grade machinists who are capable of doing almost any operation, but there are certain specialists for coil winding, welding and heat-treating. Each bench has adequate working space and is well lighted. Illumination is provided by overhead daylight fixtures with an output of twenty lumens per square foot on the working plane. Ample glareless light is essential in doing many of the close jobs of fitting or making pieces by hand and it has been a big factor in achieving satisfactory working conditions.

GETTING TOOLS TO THE JOB

One of the problems of shop management is the method of getting tools from the tool crib to the machine and back again. The older method of having each man go to the crib and get his own tools frequently involved quite a loss of time, during which his machine was generally idle. Many methods have been devised for eliminating, or at least minimizing, the loss of time.

Messengers.—Some shops have used apprentice boys to get the tools from the crib. Others use messengers, boys or men, who have regular schedules for picking up tool orders and delivering tools to the machines. Flashing lights sometimes call tool messengers and save loss of time waiting for a regular scheduled trip. One tool plant put in a pneumatic-tube system for taking tool orders to the tool crib and for dispatching such small tools as would go in the tube carriers.

Transport System.—The tool-transport system to be used depends somewhat on the method of planning and assigning work. In shops where the work orders go to the machines or to the department some time in advance of the date for starting the work, the foreman or his assistant can have the tools and fixtures ready when needed. In some plants, the foreman or his assistant actually gets the tools from the crib or sees that they are moved to the machine; in others, the foreman sends the operator to the tool crib for his tools. Getting tools back to the tool crib is usually the task of the men who take them out. In handling heavy tools or fixtures, the power-driven lift truck is of great assistance, in both labor saving and time saving. When tools are kept in sets or when the tools for several jobs can be transported at the same time, these trucks also help in saving time and labor.

Regardless of who gets the tools, they should be ready when needed at the machine on which they are to be used. They should, if at all possible, be secured without letting the machine stand idle, unless it can be proved that this method is most economical, which is seldom the case.

SPECIAL TOOLS

Preparation and Maintenance of Special Tools

The contract shop in handling limited runs of work has to figure carefully on the types of special tools necessary. In some instances, for example, where jigs, fixtures, or dies are required, tool costs are likely to be rather high (even when these tools are designed along simple lines for comparatively small lots) if accuracy is to be assured in the product. Good judgment must be applied if tool expense is to be held at a figure consistent with the volume of work to be produced.

Usefulness of Special Tools.—The total number of parts on which a certain set of tools is to be used is always problematical when considering contract jobs. The work may be continued from contract to contract, or one order may represent the entire amount of business to be developed around this particular item. An entirely new product or some modification in a product found desirable in usage may necessitate revamping of various tool details, which presents another factor in the problem of fixing upon what will be justifiable outlay for special tooling.

In bidding on work, tool costs must be studied carefully, for whether the tools are chargeable directly to the customer or, on the other hand, absorbed as an item of job expense by the shop itself, the outlay for their construction must be considered in making up any estimate on competitive work. This is especially true where jobs are of short duration only and where, as a consequence, the tool expense is a very appreciable percentage of the total cost of the work.

Cost of Upkeep.—There are also other points to be kept in mind in this connection. Not only the first cost of the tools but the cost of upkeep, resharpening, and possible repairs are of importance. Sometimes, where the number of parts required is not sufficient to warrant close insistance on proper preparation of material, there are other considerations. Castings, forgings,

sizes and forms of bar stock, excess material to be removed in machining, all must affect machinery time and tools very seriously. Diverse requirements in grinding of cutting tools under such conditions result in serious loss of time both in sharpening tools and in resetting. The percentage of "down time" under unfavorable conditions of this character becomes an item which is not always measurable in advance under the usual job-shop operating conditions. A habit commonly developed in the smaller contract shops when estimating on "so many pieces per hour" is to underestimate the amount of unproductive time in keeping tools in proper condition for doing their legitimate work. This often affects profits seriously.

Tolerances.—Another factor to be studied is the relation of tolerances set for the job in their direct bearing on requirements with reference to cutting conditions of the different tools. Obviously, where close tolerances are specified, something more in tool sharpening and setting is called for than where greater leeway is permissible between high and low limits. This applies, though in different degree, to both roughing and finishing tools; for where close dimensions in bores or outside diameters are required, roughing tools should receive sufficient attention to assure a uniformly disposed amount of material for final finish cuts, otherwise the finished work may be outside the permissible limits of error.

The foregoing refers particularly to such work as turret-lathe products where, because of the general character of the piece, external and internal surfaces are customarily machined with cutting tools without final grinding operations. In some cases, grinding facilities may not be available for the kind of job in hand.

On some classes of work where very long runs are regular practice, operators have tried the plan of grinding and sizing tools at definite intervals measured by elapsed time or after a given amount of work has been produced. Ordinarily, the moderate-sized contract shop has no run of work sufficiently extended to warrant such procedure, even though desirable features may be observed in the custom as it prevails in certain production plants. On the contrary, the majority of shops must watch their sizes closely and be prepared to set and grind tools to size whenever readjustment becomes necessary.

Logically, it might be supposed that as many parts of a given kind might be machined in the small shop as in the big production plant before tools become dulled, assuming similar equipment to be applied in both places. However, as already suggested, the small lot of castings may not be in the same class with a foundry production job where surplus metal is held to a minimum, cored work is accurately produced, and the metal itself, whether ferrous or nonferrous, is of such uniform character with respect to machinability that maximum endurance of cutting tools is taken for granted.

Similarly with forgings, a large order justifies an expenditure in drop dies and allied tools that is not feasible with the small lot, particularly where an entirely new product is being turned out in which modifications may be found desirable after a period of actual service under the varied conditions set up in the general market. Consequently, as with the casting problem, so-called "precision" parts are not to be expected from the forge shop, and the small lot of "raw" stock will therefore require somewhat more time to machine piece for piece. Furthermore, a little closer attention will be required to maintain the cutting tools in proper condition.

Tool and Cutter Grinders.—Tool and cutter grinders built for sharpening and servicing all classes of milling cutters, reamers, boring and turning tools, and the like are useful for various other kinds of grinding operations of a special nature where either centers or holding fixtures or a vise can be applied for securing the work. It frequently happens that because of the versatility of such a machine, it is tied up on some special job at the moment when it is needed for regrinding a cutter, a counterbore, or a boring head of some kind that has been removed from a machine. In that case, if the tool can be mounted between centers, it is often advisable to place the job in the lathe and apply a portable grinder to the work.

Value of Special Tools

One advantage an older shop has over the new one is the accumulation, in a series of years of operation, of a lot of tools for various special purposes, as screw machines, turret lathes, and power presses. To a specialty and contract shop such an accumulation of appliances is a real asset, for many times they

will include among the stock on the tool shelves certain types of turret and cross-slide tools and also certain dies that can be used for some special run of work where the cost of making new tools would be prohibitive for a short order.

This does not mean that any holdover tool may prove of value for any job that comes along. Press tools are usually made to suit each job, and ordinarily screw-machine tools, as well as the larger ones for turret lathes, must also be built to accommodate the work to be done. But there are many parts coming into the shop to be made for which the tools on the shelves may often be used in a satisfactory manner. This is true not only of box tools and other turret tools but also of some kinds of press tools for conventional work, for example, washers, shims, and other parts with established outlines.

Forming Tools.—Forming tools grow in number after a few years of operation of a screw-machine department. In time there are many classes of such tools—collets, box-tool cutters, etc.—and many of them are adapted to turning out special nuts, gracefully curved machine handles and levers, special boltheads of acorn or other pattern. Special taps, dies, and reamers also accumulate in time, and different odd drills and counterbores become part of the stored equipment in the toolroom. A proper storage and record system makes all these available whenever needed. This often saves making or buying an entirely new tool or set of tools and is to the advantage of both shop and customer.

Piercing and Blanking Tools.—A well-known shop which makes a specialty of small stampings, such as miscellaneous sizes of washers, disks, and shims, has accumulated, after some little time of operation, a large stock of piercing and blanking tools which are adapted to many combinations of washer dimensions—outside diameters and hole sizes—and a large proportion of orders are filled by means of this accumulated stock of tools. It is rarely the case that new tools are required, except for replacement of worn-out sets. It is true that the common variety of tools is not so economical in production as compound or gang dies would be. On the other hand, they are usually suited to short and medium runs of work and their immediate availability for hurry-up jobs offsets the fact that they are not such rapid producers as the more expensive tools would be.

Stamping Dies.—There is another firm that exists largely on stamping out sheet-metal parts such as are used for gas and electric ranges. These are largely rectangular in shape and fairly large in area. During several years of supplying stampings of this character to stove manufacturers, a line of dies has been accumulated which would cost a great deal of money to duplicate, but which have long since paid for themselves. These will still continue to be good producers for years to come. The fact that they are built to adjustable dimensions adds to their value to the press shop, for they can be set to cover wide ranges of plates and also to vary the positions of pierced holes as required. The adjustable feature is liberal in its scope and calculated to take care of reasonable future changes in design of members used on the ranges referred to.

Users of press brakes, large and small, find that after a time a variety of dies and tools have accumulated that are useful for various purposes in addition to those for which they were originally built.

Special Tool Work in the Small Shop

The special tool work for which the small shop is responsible may include many items and units quite closely allied to the same class of work in the big factories; that is, certain lines of jigs, fixtures, and dies come to the small shop for design and construction. These must often be laid out for what is really high-production purposes, although they may be intended for service in some specialty shop which, while confined to a limited variety of work, really intends to produce that work at top speed and least possible factory cost. Consequently, it is well for the small-shop manager to be interested to a degree in up-to-date methods in design and operation of that class of tools.

There are certain things that designers of modern jigs and fixtures must consider at this time which were formerly thought rather unimportant. That is due in part to the use of faster working tools than were possible with the earlier carbon-steel drills and other cutting tools. High-speed steels have brought about radical changes in speeds and feeds on nearly all classes of machining operations. As a result, the ratio of time between loading the work in such tools and the actual performance of the operation of machining the job has become of great impor-

tance. Formerly the waste of a few seconds more or less in putting work into jigs and removing it after completion was of much less importance than it is today.

Improved Handling of Jobs.—The designer today is obliged to find methods for improving on all past performances with respect to handling of jobs in and out of tools. The high rate of speed and feed for drills and other tools is such that many earlier means for placing and securing work in tools have become obsolete and out of the question. And then, too, the extension of the use of multiple-spindle and gang drills has made it important to go further with improved methods of getting work in and out of jigs because of the very high rate of production under such tools. Furthermore, the use of several drills at once working on a piece has necessitated designing for better resistance to deflection and movement of the work while under such operations. This means a sturdier job and one in which metal is so placed that it provides strength without special addition in actual weight of the jig itself.

Modern chucks with quick-change features to aid in shifting from drill to drill or to reamers and other tools have speeded up the finishing of work in the jig, and this has made it desirable for the designer to provide equally convenient methods of changing drill bushings (slip bushings) in order that the advantages of the quick-change chuck shall not be wasted in the process of shifting bushings for the different tools.

The man designing such special tools has an equal interest in milling fixtures where he has the same problem of placing and removing work in the least possible time. With manufacturing milling machines of the continuous and other types the work goes right along as fast as the operator can put the job in place and get the finished piece out of the fixture. Something similar is sometimes applicable to drilling operations where a transfer jig may be designed for sliding work along from one spindle to another with drills, reamers, and taps operating in the series of spindles.

In general, with both jigs and fixtures, extra care must be taken to prevent springing of either work or jig under drilling or milling action, and of course clamping without liability of spring is a first essential. Sometimes it is easier to support the work against cutting pressure than it is to find the best spot to

locate the clamping devices in order to avoid distortion just by means of these clamps.

The Toolmaker's Opportunity

A few words may well be said about the open field for the skilled toolmaker and the opportunity for interesting and important work in the special-tool branch of shop work. With the development of the mechanical industries and the improvement in equipment the diversity of work coming to the tool- and diemaker becomes more and more conspicuous. There are, of course, certain classes of special tools which may be made on a production basis, but in nearly all instances most of the work on a die, a jig, or a fixture is an individual job with little of the duplicate nature attached to the work. Only in exceptional cases, as in large-production factories, is there any great amount of repetition in making special tools. Consequently there is little opportunity for the toolmaker's job to become a monotonous and tiresome one. As an illustration, the usual stamping die is suited to very long runs of work before it needs to be replaced. Similarly many other kinds of special tools are really a single job with definite features not likely to be exactly duplicated in other projects of the toolroom. This applies naturally to details other than standardized die shoes, punch heads and screws, and fastening devices in general.

Where large production is necessary and work must be distributed among many shops, the question of fixtures is most important. Such a case is the making of rifles or other munitions in a national emergency. Here hundreds of fixtures are needed and skilled toolmakers are scarce.

In such cases it is quite possible to make a few sets of *master fixtures* with the greatest precision possible. These master fixtures can then be used to make the working fixtures for distribution in the many shops which are to make the rifles. Once these master fixtures are made, the working fixtures can be made by men and women who need not be highly skilled. Jig bushings have been so standardized that they can be purchased easily and quickly. Production of working fixtures can be greatly increased by such a method.

Varying Processes.—Even the means and processes followed in special-tool construction are of a widely varied character.

In some instances the lathe faceplate is used as a means of swinging the work; at other times the milling machine or some other piece of toolroom equipment is used according to the facilities of the shop or with regard to which machine may be available at the time. The jig borer and other modern designs have increased the capacity of the toolroom for many kinds of work; and progressive methods of making precision tools have added much to the tool- and diemaker's opportunities to produce work of the highest order of accuracy.

The toolroom in the large-production plant— and sometimes in smaller shops—offers a fine chance for the handling of gage work as a specialty. This line of work is especially important in many places. Almost everything is now manufactured to a system of limits and tolerances and many gages for maintaining these manufacturing limits are made on the spot in the plant's own toolroom. There is sufficient opportunity in this line of gage work to hold almost any skilled mechanic's interest. Naturally a real experience in these branches of toolroom activity leads in many instances to the skilled craftsman's embarking on a line of his own with the beginnings of a small shop likely to lead to a growing business as time goes on.

Building Special Tools

The question frequently arises in the shop as to whether it shall build its own special tools for any given job or farm out the work to a tool and contract shop. The answer to this question varies—or should vary—very greatly with existing conditions: facilities on hand for the work, the general class of mechanics available in the home shop for such work, and whether the work can be done as a filling-in order to occupy otherwise vacant tools and not-too-busy workmen. In any event, unless the shop has suitable equipment and properly experienced skilled men to use it, the preferable and safest bet is to let the work out by contract to the specialist who has had this line of business well developed and has the necessary equipment for its proper execution.

The Average General Shop.—Except in rare instances, the work of making special jigs, fixtures, dies, etc., is best placed in the hands of shops that do only that kind of work. They have adequate types of tools for doing what is necessary, and their general organization fits them for making the best use of time and

tools to perform the work. The average general shop is none too skilled in such operations and has its own particular and peculiar problems in connection with the handling of something entirely different from special-tool construction.

In the first place the very design of production tools of a special nature is a specialty of itself. The real value of such tools rests largely upon their being designed with full knowledge of what is best practice in this particular field. Except in the rare case where a real tool designer is in the employ of the shop, the layout of the tools is best left to another outfit, as well as the construction.

The Large Factory.—With the larger factories, which have their own toolroom organizations, the case is entirely different. Their toolroom forces and equipment are adequately prepared for such work as may be wanted in the way of jigs and fixtures. Yet, even some of these plants prefer to place contracts outside for any extensive lines of new production tools of a special character. They recognize the capacity of specialists in the field to produce the best possible equipment and on occasion place the work in such shops. This is apt to be the case where the factory tool department is too rushed to take on additional work.

Sometimes the management thinks that it might be cheaper for the plant to build all its own special equipment, but this would probably entail the purchase of a great deal of new machinery which the contract tool shop already has on hand. For this reason every industrial community has seen the specialty or tool shop start up and grow largely upon business turned over to it by local manufacturers operating large plants. Few of the large automobile plants make all their own tools, and special machines are almost never built in their shops.

One well-known tool shop built up a large volume of business upon the activities of a couple of manufacturers who passed along most of their jig and fixture work and all of their die construction. The arrangement worked out to the advantage of all concerned and is not an uncommon experience in this country.

Under these circumstances a tool shop can afford to buy the latest and most effective types of machine tools for its purposes and divide with the customers some of the benefits to be derived

from the use of such accurate and productive equipment. The amount of time saved, as compared with less effective means, results in a lower shop cost of the tools themselves and places them in the hands of their purchasers at the earliest possible date.

SUITABLE LIMITS AND TOLERANCES

Most plant managers and shop executives appreciate the advantages of a system of suitable limits and tolerances for use in the production of their various metal parts. This is true particularly where interchangeability is necessary, as in the case of a great portion of today's products. But there is a belief in some quarters that manufacturing tolerances in the main are developed for only the highest grade of goods. These executives believe that any fixed system of the kind will be something of a handicap to output where work of a lower grade generally is being produced.

While this may be true in some instances, it depends largely upon the size and character of the work and its volume. Limits set too closely will prove a handicap. If the lot of work is very small, close tolerances or close holding to whatever tolerances are applied will be a nuisance and usually an unnecessary hindrance to getting that work through the shop.

Considerable misunderstanding exists as to just what is a suitable tolerance in many machine-made parts for articles that sell at a low figure. Some shop managers who recognize the advantages of close limits on expensive units will overlook entirely the manufacturing advantages to be gained by somewhat similar limits on even ordinary classes of work turned out in volume. They view the expense of gages for holding tolerances closely on such products as someting of a waste of good money, and time as well.

Advantages in Assembly.—It must not be overlooked that one of the important reasons for any system of tolerances at all is the advantage gained in the process of assembly. This is far more important than many realize. In fact, the advantages are well worth while when one considers what occurs in the putting together of a lot of inexpensively manufactured elements into a complete and cheaply distributed article.

Work carelessly gaged in the production departments of a factory leads to costly work at the inspectors' bench and still

more expense in assembling. Where indifferent limit systems are used, the inspection system will be apt to be equally free-and-easy and everything that is wrong about a component comes to light only when the assembly crew handles the job. The elimination of "scrapped" work, before it is scrapped, that is, the avoiding of making scrap in the first place, is of itself a justification for making limit gages and using them at the proper point in the production line.

Nevertheless, improperly set limits—if too refined—lead to unnecessarily high production costs, or if set too loosely, they lead to production of parts that are not interchangeable.

It is true that with high-priced articles more time may be used in assembly without affecting results to the same extent as when all the economies of machine work on a cheap article may be eaten up by the waste at the assembly bench just because of careless setting of limits and tolerances. Some shop operators do not realize that an article that sells for a few pennies requires close holding to sizes of all parts just to avoid throwing assembling costs out of balance.

Advantages in Replacement.—Most metal parts of machines and apparatus require replacement at some time or other. If a manufacturer assumes the responsibility of keeping replace parts ahead for his customers, he is bound to make these parts to such practical tolerances that they actually will be able to replace parts in use, and will not have to be hand-fitted by the user.

This matter of limits and tolerances is really one of the first that should engage the attention of the shop manager when he is getting ready to manufacture any piece of equipment. He should weigh the importance of all dimensions as given on the working drawings and the limits represented by the working gages to be used in his manufacturing departments.

As a practical manufacturer he will know that in many cases limits are apt to be set to conform to a general rule without due attention to the specific job now under consideration. For example, the exact limits—high and low—for a given type of spindle might not be like those for some other piece of the same nominal diameter. In other words, some deviation must often be made from standard practice with definite sizes of work. Limits should be set by the use to which the piece is put, rather than its size.

It may be that there are practical difficulties in operating with too close clearances between shafts and bearings on certain kinds of jobs. If clearances between mating members are to be increased, then it is feasible, usually, to take a little more allowance in the setting of limits for one or both members, with some advantage in the production of such pieces. The point is that a fixed set of tolerances for a given diameter is not to be held to in setting up limits for everything of that same size regardless of the particular application in a machine. The tolerances standardized by the American Society of Mechanical Engineers are a good guide.

Speed and Weight Affect Clearance.—Among other factors to be thought of is the question of speeds of parts, whether very high, very low, or merely nominal. Weight of parts operating or carried by a revolving spindle must also be considered, as well as the means of lubrication. But through all this study of practical working limits must run the idea that excessively close tolerances where they are not needed will handicap the shop seriously. This is especially true with some peculiarly shaped piece where it may be impossible to find any justification for very close work. But if the drawing calls for such close work, the shop manager must make an effort to gain more latitude if he wishes to make any real headway with the job.

The general treatment of the subject of limits and tolerances brings up the matter of location (in a machine or otherwise) of the part in question and the point as to whether the part is a fixed component or a running member of the machine.

This consideration introduces also the matter of surface finish, which is often a leading factor in determining the limits to be fixed for a given shaft or spindle dimension or for a stationary part that must be fitted to some corresponding piece. Obviously, where a stud or similar element is to be pressed into a hole in a plate or set in and afterward riveted in place, the character of its surface finish is relatively unimportant because it is subjected to no wear after it is assembled in place. If, however, it is a shaft fit in a coupling or other part likely to be removed at times (as in the case of an axle in a wheel), the surface finish is a more important matter. In either instance the limits set for finishing the part and for sizing the bore or receiving hole must be defined if assembling is to be simplified. Otherwise

hand fitting with consequent delay will be called upon in putting parts together.

Importance of Finish.—With a running shaft or spindle the finish of the surface, as well as the actual diameter of the bearing, is important in reference to the closeness of the limits. These should be set with due thought as to accuracy of operation, life of wearing surfaces, and provision for introduction of lubrication even with maximum shaft size and minimum hole diameter. Otherwise too great freedom may develop in some bearings when assembled, or on the other hand, too little clearance with consequent heating of bearings.

Some of these points often have to be settled by the man running a shop—either large or small. Specialty manufacturers too are frequently faced with necessity for fixing upon most economical and practical limits for many classes of work.

It may be added here that in any shop where the matter of duplicate-parts production arises, the detail of limits and tolerances must be viewed with sound, practical judgment. It must be remembered that manufacturing tools, and even shop gages, are subject to wear. Reamers, for example, hold their sizes for only a limited time and like other sizing tools require attention frequently even with ordinarily reasonable limits. To cut these down too fine means excessive resetting and sizing of tools. And each degree of refinement added to practicable limits means disproportionate expense. Roughly speaking, a tolerance of a couple of "tenths" will mean much greater difficulty to the average shop than will be found where four or five ten thousandths is stipulated.

CHAPTER 6

WORK IN THE SHOP

ASSIGNING WORK

In regular production shops each man and machine usually have an assigned task. The man and the machine make the same kind of parts day after day for fairly long periods, if not continuously. In other shops, however, the assignment of work is constantly changing. So far as possible it must be assigned to the man and to the machine best fitted to handle it. And it must be distributed so as to keep the work flowing smoothly instead of being piled up around one machine.

This means that someone thoroughly familiar with the men and the shop equipment must be in position to schedule the work in such a way as to keep the various machines busy without assigning more to any machine than it can handle without delay. Then, should it become necessary because of a machine breakdown or illness on the part of one or more men, the work must be reassigned in order to minimize the delay. This requires real executive ability, and the man who can keep work running smoothly through the shop deserves substantial recognition.

Job Ticket.—Where a job requires the use of several machines, a ticket is frequently made out for each machine. These tickets are placed on a board or rack that has a place for each machine. By placing each new assignment at the back, the jobs retain the order in which they come to the man who schedules the work. They can, however, be shifted to meet emergency or rush demands.

Instead of separate tickets, a single job ticket can be used and moved from machine to machine. This does not give so much advance notice as the separate slip, but it answers in some places. It is usually moved as soon as the work is started on the previous machine. Then there is the move ticket to show where the job is to go next.

The same method can be used for hand work by assigning the work to the men best fitted for it instead of to a machine.

The main object in all such plans is to have the work flow smoothly by having the next job ready without delay. Lost time between jobs adds to the cost without benefiting anyone.

Part of the object of this planning and scheduling is to know what men or machines will be available for the work as the different operations are to be performed. Only in this way can work be planned intelligently and estimates and promised deliveries made with assurance. Without a good planning method all such estimates are largely guesswork.

SELECTING THE BEST METHODS

Here S. C. McDowell, of the time-study department of Westinghouse Electric and Manufacturing Company, shows how they select the best method to be used in punch-press work. Similar methods can be used for other operations.

Manufacturing plants are constantly faced with the problem of selecting the best method to be used in producing a specified quantity of a given unit. This is particularly true in punch shops where any one of a number of methods often can be used to make the same part.

Where repeat order quantities fluctuate according to rapidly changing market requirements, or to suit customers' demands, the problem can be very complex. Often each order must be reviewed prior to actual fabrication. To review each order and make adjustments to ensure use of the most efficient method involves considerable clerical routine.

In a small shop, where few items are made, such a review of each order may be of small consequence. In a large shop, such reviews greatly increase overhead expense. A record of the method used for the first order will make a second review unnecessary, so long as the quantity to be made permits economical production by the original method.

All items manufactured in the punch shop do not change radically in quantity each time they are ordered. There are usually a number of parts, however, that fluctuate widely in order quantities; if these are not properly handled an inefficient condition will be created. Considerable loss of both time and money may be experienced.

One of the duties of the time-study department in the East Pittsburgh plant is to lay out the sequence of operations to be

followed by the shop when fabricating a metal stamping. The recorded activity list involves some 50,000 different items, approximately 500 new items being added each month. Daily orders, including both new and repeat jobs, approximate 425. These are handled by five time-study men. It has been found impractical to review each order before it is issued to the shop because of the interference with production schedules and clerical routine. So a system was devised to analyze only those items which have changed in quantity sufficiently to warrant a more efficient method of manufacture. This system proved to be the most convenient and accurate used to date.

To set up this system, the various production methods in use were reviewed and several chosen which best suited this shop. Any specialized methods for exceptionally large quantities will not be considered here, for an item requiring a highly specialized setup is so prominent that there is no danger of its being manufactured by any other method. Methods chosen as a manufacturing basis are the bench, the simple die, the interchangeable shoe, and the compound die.

Simple Tools.—The bench method is used when it is undesirable to set up machines and uneconomical to make any form of dies, owing to the small quantity of pieces to be made. Details are formed completely by hand with ordinary bench tools.

Simple-die methods are used when the quantity of pieces to be made is too great to be formed on the bench, and is still not large enough to warrant making dies. These first two methods, when properly recorded for the same item, can be used as required, depending on the quantity of pieces on order. Simple dies are so named because they perform only one operation at a time. An example would be a detail requiring the punching of two holes. This would require two separate operations and a change of gages to punch the holes.

The interchangeable-die-shoe method is used when the quantity of pieces is too large to use the simple-die method and yet is not of sufficient quantity to warrant construction of an expensive die. In this method the dies perform several operations at one stroke of the press, and they are constructed with only sufficient details attached to facilitate their economical operation. A common die shoe, into which the dies are clamped and removed each time they are used, is provided. This method was created

to fill the gap between the simple-die and the compound-die methods. Interchangeable dies are made so that the addition of certain details and a die shoe will convert the tool into a compound die. This method, once used, is never superseded by either of the first two methods.

Compound Dies.—Compound dies are used when the quantity of punchings is sufficient to warrant an increased die cost. Dies for this method are complete in every detail and their operation is the most economical of the four mentioned methods. It is only superseded by some specialized method.

The two major factors to be considered when choice of method is made are tool or die cost and labor cost. No die cost is included in bench-method estimates, but the cost of hand tools and their upkeep is prorated to all items so made as part of an expense charge. Similarly, the cost of making simple dies is absorbed in an expense account and charged indirectly to the item concerned.

Die cost for the interchangeable-die and the compound-die methods is added directly to the labor cost of the item for which the tool is made.

The type of labor necessary for the different methods varies widely, due to the nature of the work involved. It would be inefficient to have a skilled bench workman operating a punch press when a less skilled workman could do the work. Labor consists of bench hands for the bench method, die setters for the simple-die method, and die setters and punch-press operators for the remaining two methods.

Ratio of Costs.—Time required for the fabrication of a stamping by the bench method is greater than by the simple-die method, but the setup time involved is less. In the interchangeable-shoe method both the setup and operating time are less than

TABLE 8.—RATIO OF COST ELEMENTS TO BENCH METHOD

Method	Die cost	Labor cost	Setup allowance	Operating allowance
Bench	0	1.00	1.00	1.00
Simple die	0	0.96	3.26	0.107
Interchangeable shoe	1.00	0.92	1.56	0.0198
Compound die	1.87	0.89	1.30	0.0173

that required by the simple-die method; yet they are greater than is necessary for the compound-die method. Table 8 lists average relations of each method compared with the bench method.

Limits Specified.—When the first order is received, provisions are made to care for future fluctuations in quantities. To do this, specifications are recorded directly on the write-up of operations being used. As an example of how this system functions, the changes made in methods used to manufacture a small bracket are given in Table 9. This bracket is used in an electric circuit

TABLE 9—COMPARISON OF MANUFACTURING METHODS
Bracket Style No 256914-A
(3 × $2\frac{1}{4}$ × $\frac{3}{32}$ in cold-rolled sheet steel)

Operation	Setup time, Decimal hours	Running time, Decimal hours
Bench method—up to 8 pieces:		
1 Shear to blank size	0 35	0 00130
2 Make complete	0 75	0 35640
3 Wash in No 2954 solution	0 05	0 00040
Simple-die method—from 9 to 2066 pieces		
1 Shear to blank size	0 35	0 00130
2 Slot, pierce, and bend	3 10	0 02945
3 Tap and burr	0 25	0 00700
4 Wash in No 2954 solution	0 05	0 00040
Interchangeable-shoe method—up to 12,000 pieces.		
1 Shear strips	0 29	0 00030
2 Pierce, slot and blank	0 40	0 00100
3 First bend	0 40	0 00160
4. Second bend	0 40	0 00160
5 Tap and burr	0 26	0 00225
6. Wash in No 2954 solution	0 05	0 00040
Compound-die method—more than 13,500 pieces:		
1. Shear strips	0 29	0 00030
2. Pierce, slot, and blank	0 30	0 00036
3. First bend	0 30	0 00121
4 Second bend	0 30	0 00146
5. Tap and burr	0 26	0 00225
6. Wash in No 2954 solution	0 05	0 00040

breaker which is becoming more popular each year. Several years ago pieces were ordered by the experimental division, and subsequently several more very small orders were received while the circuit breaker was still in the experimental stage. From long practice and experience it is possible for the time-study man to estimate at what quantity the simple-die method should supersede the bench method. In this case he specified the bench method for 10 pieces or less.

An order for several hundred brackets was received the following year, indicating that the circuit breaker was out of the experimental stage and that a more economical method of manufacture was necessary. The simple-die method was then added to the existing record card. It has been found a good practice to leave both methods on the card at this stage, for if the activity does not eventually build high enough to warrant special dies, there will be times when orders for small quantities will be requested. If both methods are on record, the time-study man does not have to recalculate for the bench method.

When a change is made from the bench method to the simple-die method, it is necessary to determine the correct quantity of pieces at which the one method should supersede the other. This is found by subtracting the allowed time per piece for the simple-die method from the allowed time per piece for the bench method and dividing the remainder into the remainder found by subtracting the allowed setup for the bench method from the allowed setup for the simple-die method. In algebraic form:

$$Q = \frac{s.u. - S.U.}{R.T. - r.t.}$$

where

$S.U.$ = total setup allowed for the bench method.
$s.u.$ = total setup allowed for the simple-die method.
$R.T.$ = total running time allowed for the bench method.
$r.t.$ = total running time allowed for the simple-die method.

In the example of the wall bracket, the equation becomes

$$Q = \frac{3.35 - 0.75}{0.35640 - 0.03645} = 8.12 \text{ or } 8 \text{ pieces.}$$

At the same time an estimate was recorded of the quantity to be fabricated by the simple-die method before a more efficient method need be considered.

This item was ordered in lots of several hundred pieces for about 6 months; then an order was received from the assembly section for 2562 pieces. It was then considered advisable to construct dies of the interchangeable-shoe type for the fabrication of this detail. When this method has been decided upon, it supersedes the two previously used methods and a new quantity limit is estimated and recorded. This quantity indicates when the record card, Fig. 107, should be again reviewed by the time-study man. To find the correct quantity where the interchangeable-shoe method supersedes the simple-die method,

ORDER NO. 256914-A | S O ITEM | ASSIGNED ITEM 2 | REQ FOR SECTION AB-21 | DEL TO SECTION E-4 | DATE WANTED 2-6-35 | DWG & SUB OR STYLE NO | ITEM

MATERIAL REQ'D FOR ORDER

QUANTITY | DWG AND SUB 54-K-735-3 | ITEM 12 | STYLE OR PATTERN 256914-A | DATE PROMISED

P O SPEC 1689 | NET AREA 6.75

NAME OF PIECE BRACKET | PROC OR FINISH 16-C | RATIO 110 | NET WT EACH .18 lb.

MATERIAL FOR ONE PIECE 3 x 2-1/4 of 3/32 C.R.ST. #1689 | MATL PRICE .043 | SCRAP CREDIT .005

NOTES | MATL COST | LABOR & O H COST | FACTORY COST EA LB

CUSTOMER | CUSTOMER'S ORDER | COST DEPT NOTES

PROD CLERK | WRITTEN BY Mitchell | SECTION E-4 | DATE 2-3 | TIME A.M. | ORDER SERVICE REF

WORKMAN'S NAME | SECTION | GROUP NO | CHECK | DATE | DWG & SUB OR STYLE NO | ITEM

OPER NO	TOOL NO	MANUFACTURING OPERATION	SECTION	GROUP OR CK NO	PIECES APPROVED	STANDARD TIME SET UP	STANDARD TIME RUN TIME	STD COST RATE	INSPECTOR'S SIGNATURE
1		Bench method up to 8 pieces							
2		Shear to blank size	AB21	7		.35	.00130		
3		Make complete	"	12		.75	.35640		
4		Wash in 2954	AB11	18		.05	.00040		
1		Simple Die Method from 9 to 2066 pieces							
2		Shear to blank size	AB21	7		.35	.00130		
3		Slot, pierce and bend	"	15		3.10	.02945		
4		Tap and burr	"	15-B		.25	.00700		
5		Wash in 2954	AB11	18		.05	.00040		

MATERIAL REQUISITION WESTINGHOUSE FORM [illegible]

Fig. 107.—Bench and simple-die methods are used interchangeably, depending on the number of pieces ordered. Both methods are, therefore, recorded on the same operation record card.

the cost of the detail by the interchangeable method is subtracted from the cost of the simple-die method, and the remainder is divided into the cost of the dies to be made. In algebraic form

$$\frac{A}{B - C} = \text{dividing quantity between methods}$$

where

A = cost to make dies for the interchangeable-shoe method.
B = total cost per piece recorded for the simple-die method.
C = total cost per piece by the interchangeable-shoe method.

For example,

$$\frac{155}{0.10 - 0.025} = 2066 \text{ pieces.}$$

The popularity of this circuit breaker kept production requirements expanding until orders being received were sufficient to stock larger quantities of the brackets. Still later an order was placed for 15,000 pieces. At this time the time-study man changed the recorded method from the interchangeable-shoe method to the compound method. The quantity where this method supersedes the interchangeable-die method is found in the same manner as above.

This system has given the time-study man a more complete control of methods; it has eliminated possibilities of active items being overlooked and has raised the efficiency of operation in the shop. This has been accomplished with a minimum of clerical routine. Time necessary for handling of paper work through the office has been materially reduced.

KEEPING TRACK OF SHOP ORDERS

Once an industrial plant has grown beyond a certain size, the method of keeping track of parts and materials can no longer be carried around under one man's hat. Some kind of system is necessary. The ideal is a system that will do the job thoroughly without becoming more important than the productive operations of the shop. This system saves time in starting work by selecting standard instructions from a master card.

Requirements of the System.—Until one delves into the subject, one does not realize how many different things a shop system is required to do. It may be called upon to perform any or all of the following functions:

1. Notify the stockroom that certain materials will be needed on a certain order.

2. Set up a system of receipts for the withdrawal of material from stock.

3. Supply route tags to identify the material as it travels through the shop.

4. Control the movement of the job from operation to operation.

5. Notify the various shop departments of the parts required to fill a certain order.

6. Determine machine load for posting on the schedule board.

7. Carry to the shop the standard time allowed on each operation of each piece.

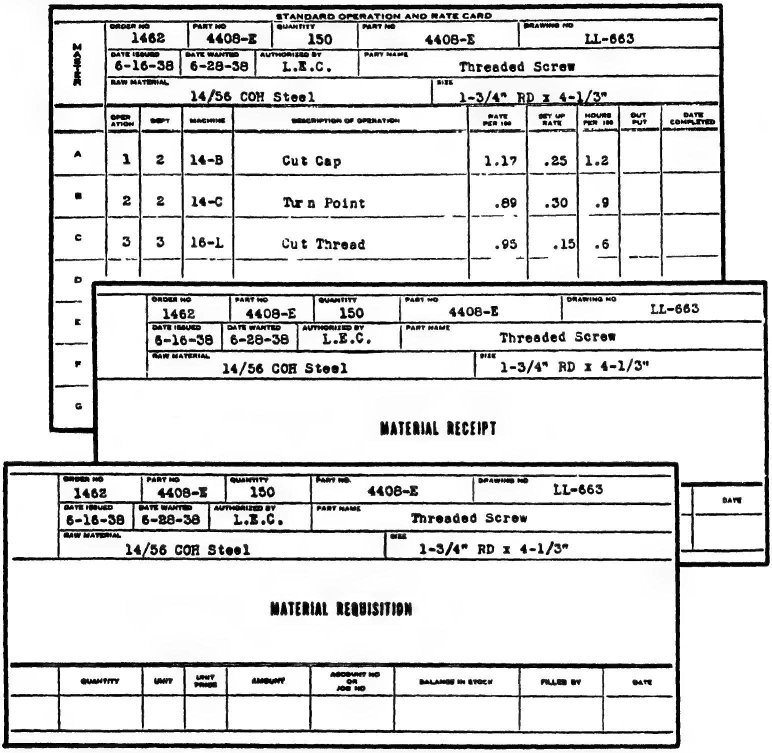


FIG. 108.—Master card, material requisition, and material receipt.

8. Advise the assembly department of the parts required to complete a given order.

When standard parts are routed through the shop, it will be readily seen that a considerable number of forms must be made out if the above requirements are to be met. Some of the information on these forms, such as the order number, the part number, the quantity, and the name of the part, will be repeated on all the forms. Part of the forms will contain complete information as to the sequence of operations and the time

allowance on each one. Others will contain only a portion of this information, usually only that part which affects the particular operation to be performed, with the other data deleted.

In order to prevent the paper work from becoming burdensome, mechanical duplicating systems have been applied to the making out of shop orders with considerable success. One such system, developed by Ditto, Inc., has the advantage of duplicating shop forms for a part order and also of setting up a master which can be used on subsequent orders for the same part,

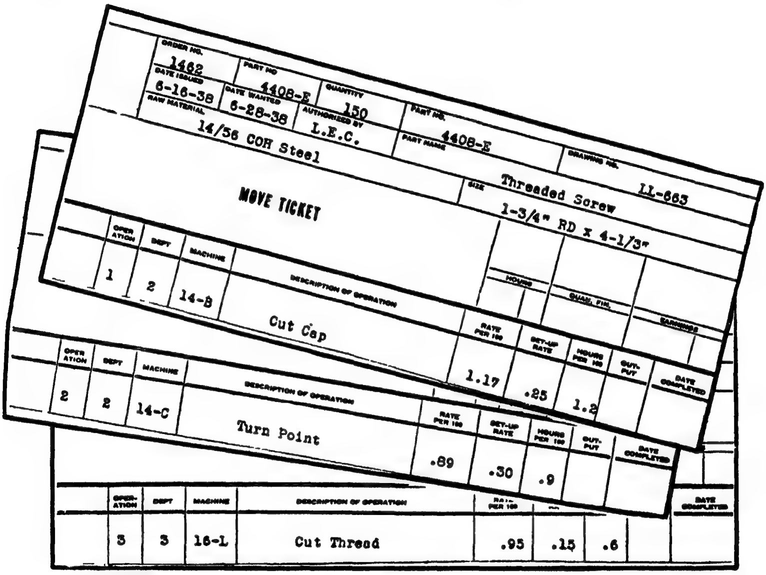


FIG. 109.—Move ticket, made at the same time as the other cards.

as in Fig. 108. The use of this master saves duplication of work and also the possibility of error on repeat orders. It is now being used by such concerns as the Chain Belt Company, the Harnischfeger Corporation and the Oliver Farm Implement Company.

The Master Card.—The system operates as follows: A master order is made out for each part which contains all the standard information, such as the part number, the part name, the drawing number, the kind of material, the routing, description of operation, and the standard time for each operation. This card is typed with a special aniline ink which enables it to be reproduced by the Ditto direct-process machine. For each

order there is a variable master strip similarly typed, which can be placed above the master card to add such information as the order number, the quantity, the date of issue, the date wanted, and the initials of the person authorizing the order.

When the order comes in from a customer, the material lists for each sub-assembly are obtained from the engineering department, and the corresponding parts order cards are taken from

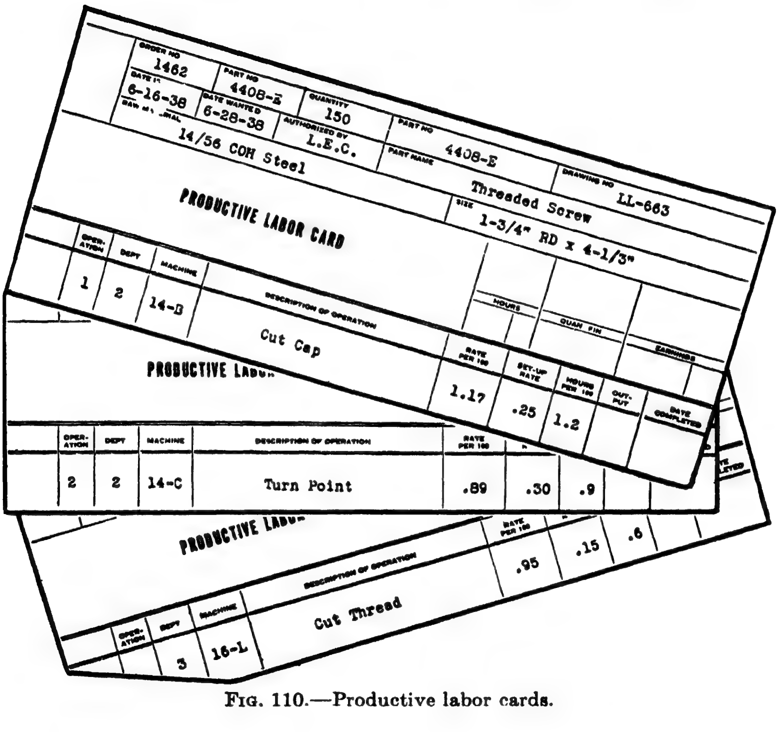


Fig. 110.—Productive labor cards.

the file. To this order master the variable strip as described above is added for each part. An advantage of the system is that selected portions of the information on a master card can be transferred to the various forms, such as to the move ticket in Fig. 109.

For instance, on the material requisition and the material receipt, it is not necessary to give the complete routing or the time allowance on each operation. All that is required is the general specifications of each piece which, of course, includes

the number required, the material to be used, and the size of the material if it is to be cut from bar stock.

Productive labor cards, Fig. 110, which are often hung on the machine when the part is in process, should contain the description of the operation and the time allowance. In many cases, however, it is desirable not to include the same information for other operations on the same part. The Ditto machine makes it possible to transfer the selected information desired by means of a series of snap guides which locate the cards correctly to receive only the information desired. On the other hand, the main-parts order card, which is used for scheduling the work through the shop, should have a complete notation of the entire routing with the standard time for each operation.

It can be seen that since the master cards are already in file when an order comes in, it is possible to save from 24 to 36 hr. in getting the work orders to the shop.

VISUAL RECORDS

It is easy to overdo the making of records. But there are certain forms, or types of records, that help in almost any kind of work. Records that can be seen at a glance, without turning the leaves of a book, can be easily studied and are very helpful.

A Simple Flow Chart.—Some shops have a running, or perpetual, chart which shows the status of each order in the shop. This type of chart is very useful and not difficult to maintain. An outline of this is seen in Fig. 111. It shows when every order comes into the shop, when it is due, and its progress toward completion at any given day. It prevents orders being overlooked, even if they have to be sidetracked for more urgent business. It saves making a lot of inquiries in the shop, since all data are in plain sight.

This flow chart was devised by S A. Crosby, chief engineer of the Speed Products Co., and makes it easy to keep a record of the progress of a large number of items going through the shop.

The board itself is constructed of a plywood backing onto which are glued sheets of drawing paper. Along the top and bottom edges of the plywood are nailed half-round wood moldings having a diameter somewhat greater than the thickness of the plywood. Over these moldings pass vertical loops of waxed string, properly spaced by nails driven into the moldings. Each

loop is made of two lengths of cord, one white and the other colored, tied tightly enough to hold the loop snugly on the moldings at the top and bottom.

The chart proper is laid out with its vertical scale representing number of parts, heavy horizontal lines being ruled for every 10,000 units, with lighter lines in between. The base is composed of sections for the individual parts, each section being

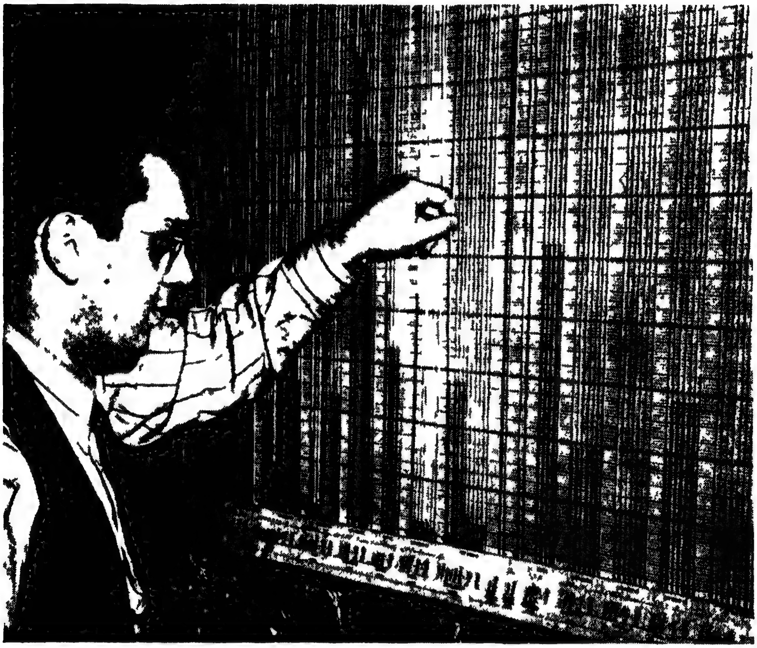


FIG 111 —Quick adjustment of a colored string to correspond with work done keeps this control chart up-to-date The status of any batch of parts, whether inside the plant or at an outside shop, is revealed at a glance

divided into columns for every operation required by that particular piece. For parts purchased ready for use from outside suppliers, there are columns marked "received" and "issued." In the case of parts sent outside for hardening or finishing, there are also columns marked "out" and "in" In each case there is a column marked "issued" Every column has its corresponding string

When production starts, all strings are set so that the joint between the white and colored portions comes at the bottom,

or zero line, leaving only white string showing. At the end of the first day's production, each string is raised so that its colored portion indicates the number of parts which have passed through the operation it represents. Day after day the same procedure is followed, the colored string climbing like mercury in a thermometer. When one operation is completed on the total number of parts in the lot, the colored string is raised to the top of the chart, showing that this operation is finished and that the parts are ready for the next operation, which is similarly indicated. Thus at any time a glance at the chart shows the exact status of any batch of parts.

When all operations on a given part are completed, the chart so indicates and the parts are sent to a stock room. If they are sent outside for further operations, the "out" column shows exactly how many have been sent and the "in" how many have been returned. When a sufficient number of each part required is in stock and assembly is to begin, the necessary requisitions are issued and the number of parts issued by the stock room to the assembly department is indicated in the "issued" column of the board.

Posting can be made as often as desired from tickets filed by the foreman or stock clerk. Foremen, superintendent, and others can consult the chart as a guide to what has been accomplished and to what should be scheduled to bring low parts up to the level required to keep machines busy and production moving in step with assembly. The chart also keeps purchasing, production, and stock departments informed and enables them to plan their work in a systematic manner, and permits management to follow the progress of work through the plant and see that assembled units will be ready to meet delivery date.

Workday Calendar.—In this connection it is well to consider the type of workday calendar prepared by Lucien I. Yeomans of Chicago and shown in Fig. 112. This shows the actual number of workdays between any given dates, making allowances for Sundays and holidays. With a calendar of this kind available, it is easy to see just when work can be promised safely without any mistakes as to the number of working days available.

Delivering work when promised, without excuses as to forgotten holidays or other oversights, pleases customers and is a great asset in any business. It frequently decides the placing

WORKING DAY CALENDAR

1939	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1939
OCT.		546	547	548	549	550			551	552	553	554	555			556	557	558	559	560			561	562	563	564	565			566	567	OCT.
NOV.	568	569	570			571	572	573	574	575			576	577	578	579	580			581	582	583	584	585			586	587	588			NOV.
DEC.	589			590	591	592	593	594			595	596	597	598	599			600	601	602	603	604				605	606	607	608			DEC.
1940	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1940
JAN.		609	610	611	612			613	614	615	616	617			618	619	620	621	622			623	624	625	626	627			628	629	630	JAN.
FEB.	631	632			633	634	635	636	637			638	639	640	641	642			643	644	645		646			647	648	649	650			FEB.
MAR.	651			652	653	654	655	656			657	658	659	660	661			662	663	664	665	666			667	668	669	670	671			MAR.
APR.	672	673	674	675	676			677	678	679	680	681			682	683	684	685	686			687	688	689	690	691			692	693		APR.
MAY	694	695	696			697	698	699	700	701			702	703	704	705	706			707	708	709	710	711			712	713	714		715	MAY
JUNE			716	717	718	719	720			721	722	723	724	725			726	727	728	729	730			731	732	733	734	735				JUNE
JULY	736	737	738		739			740	741	742	743	744			745	746	747	748	749			750	751	752	753	754			755	756	757	JULY
AUG.	758	759			760	761	762	763	764			765	766	767	768	769			770	771	772	773	774			775	776	777	778	779		AUG.
SEPT.			780	781	782	783			784	785	786	787	788			789	790	791	792	793			794	795	796	797	798			799		SEPT.
OCT.	800	801	802	803			804	805	806	807	808			809	810	811	812	813			814	815	816	817	818			819	820	821	822	OCT.
NOV.	823			824	825	826	827	828			829	830	831	832	833			834	835	836	837	838			839	840	841		842			NOV.
DEC.		843	844	845	846	847			848	849	850	851	852			853	854	855	856	857			858	859		860	861			862	863	DEC.
1941	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1941
JAN.		864	865			866	867	868	869	870			871	872	873	874	875			876	877	878	879	880			881	882	883	884	885	JAN.
FEB.			886	887	888	889	890			891	892	893	894	895			896	897	898	899	900			901	902	903	904	905				FEB.
MAR.			906	907	908	909	910			911	912	913	914	915			916	917	918	919	920			921	922	923	924	925			926	MAR.
APR.	927	928	929	930			931	932	933	934	935			936	937	938	939	940			941	942	943	944	945			946	947	948		APR.
MAY	949	950			951	952	953	954	955			956	957	958	959	960			961	962	963	964	965			966	967	968	969			MAY
JUNE		970	971	972	973	974			975	976	977	978	979			980	981	982	983	984			985	986	987	988	989			990		JUNE

Less than seventy per cent of the days are available as straight time working days. Keep this in mind when making promises and scheduling output. Broken promises make no friends. Add to or subtract from the number shown at any date the number of working days wanted and refer to the calendar months and days on the margin to find the date corresponding to the working time required.

FIG. 112.—Workday calendar for planning future deliveries.

of orders, regardless of minor differences in price. Dependability either in an individual or in a concern is an asset that cannot be measured in dollars.

PRODUCTION CONTROL

Production control, according to George T. Trundle, Jr., who has had a very wide experience in many industries, is simply the application of common sense to the solution of those responsibilities of management which have to do with increasing productivity and decreasing costs. It consists in getting certain necessary facts and planning on the basis of these facts. Production control may be likened to the running of a railroad. It is not by accident that trains are on time and make connections. It takes detailed planning that goes deeper than just the making of schedules. It involves the condition of the locomotives, cars, and tracks; the material that goes into the equipment; the skill and reliability of employees; and reasonable allowances for unforeseen delays.

A survey of a large shop of over a thousand men showed that they were put to work every morning on whatever jobs the various foremen thought were needed. There was no schedule as to what jobs were needed most or how much time they would take. They made too few of some parts and too many of others, so they never came out even in the assembly department. This meant that the output of completed articles varied widely from day to day.

There was no planned purchasing. When someone reported a shortage of material, the purchasing agent bought more, but with no planned volume to keep production moving. He had no standards as to materials, and the variety in steels caused loss and delay in the shop. In one case 30 per cent of a certain part went into scrap because of wrong material.

This was not a second-rate company making an inferior product. It had an excellent reputation. But it lacked control in both purchasing and manufacture.

Plan of Control.—When control was put into operation at this plant they increased production, lowered costs, cut hours, and raised wages. The method was as follows:

1. *Establish the Desired Volume to Be Produced.*—No intelligent planning can be done in a plant except on the basis of anticipated

output. This means going to the sales department and getting a carefully conceived sales estimate. Of course, the amount arrived at does not have to be rigidly adhered to. But some fixed amount must be established, at least as a yardstick, in gaging operations all the way to finished product.

2. *Determine Specifications.*—There should be definite specifications for all the materials entering into the product; specifications for each part entering into the final product; specifications as to the degree of machining, finishing, or other characteristics of the various parts. All this information should be obtainable by working with the engineering department. When this job is done, it will have set standards for raw materials, for manufacturing processes, and for finished product—and the job then becomes one of arranging operations to conform to these standards.

3. *Check Tools and Equipment.*—Definite specifications for the product and its various parts have been determined. The question now is, "Are tools and equipment capable of turning out a job that will meet these specifications on the basis of the materials to be supplied?" If investigation shows that some of the equipment is not capable of functioning properly, new and suitable equipment must be supplied.

4. *Determine Standards of Work.*—With specifications definitely set and with equipment and tools in proper shape, the next job is to determine as nearly as possible the amount of productivity to be expected on each particular job. Obviously, production cannot be properly coordinated—like the trains that meet in a railroad station—unless rate of production of various items is reasonably ascertained in advance. In fact, until standards of work are determined, there is no accurate way of estimating how many men are going to be needed to perform the work.

Work standards can be established satisfactorily for all practical purposes without going too deeply into time study. Nor is piecework or some other incentive method necessary in order to gage accurately what should be the productivity of a good man on a certain job. *It has been argued that piecework is a device whereby the worker may make up for inefficient management*—and there is considerable to be said for this point

of view. Knowledge of equipment and men and plain common sense point fairly accurately toward proper standards of work.

A good shop executive, can set up standards with the aid of past experience and information supplied him by equipment manufacturers. They know the output to be expected from their own machines, and can set up work standards which, for all practical purposes, should be sufficient. The job is one of knowing the capacity of equipment in relationship to the material to be handled, and then making proper allowance for the human element.

This gives the essential and known factors with which to work. We know the exact nature of the raw materials, the specifications covering all items to be produced, the equipment needed to produce such items in accordance with specifications, and work standards specifying how much time it will take to turn out a given number of every item. With this foundation, planning and scheduling becomes a matter of arithmetic and horse sense. For production purposes the assembly room becomes the Grand Central Station. The job of planning and scheduling is simply one of seeing to it that all trains arrive at the Grand Central at the same time.

That, in substance, is production control. There are many secondary items which might well be discussed in detail, such as the advantages of good lighting, which helps men do better work, proper storing and arranging of materials, which saves time and effort, or the routing of materials through the plant in such a way as to make for minimum handling. But all these things become obvious as soon as the main principle is once grasped and the effort made to put it into effect.

It is hard at first for some people to understand the fact that production control with respect to a specific item of manufacture is not confined to the physical work on that particular item, but must embrace control of *all* the factors that have a bearing upon the production of that item.

With thorough controls established you know that supplies and materials are right, that specifications are right, that equipment and facilities are right, that the number of men employed is right, that products will be produced, ready for delivery at the right time; and that work in process and inventory are balanced so that no excess working capital is tied up.

Production control is not easy. It involves digging into facts and figures, overcoming the lethargy of plant executives, educating foremen to new ideas, training workmen to different ways of doing things. But the principle of the thing is simple. You can see it perfectly at work in any symphony orchestra. There is a conductor who keeps time. There must be timing and coordination, or the result is not music. And in manufacturing, there must be timing and coordination directed by "production control"—*or the result is not profits.*

CHECKING THE BOTTLENECKS

Prevention of bottlenecks is necessary to secure maximum output from any plant. The method developed by the Westinghouse Electric and Manufacturing Company is described by D. J. Hucka of the generator works department of that company. Briefly, the method is to know the approximate load, or work, scheduled ahead for each machine. This indicates the bottlenecks in the machining section before they really occur and allows plans to be made for avoiding them. All new business is dated in accordance with this load line. Knowing the load ahead, work supervisors can plan ahead as to the number of people and the shifts necessary to handle the work. This helps in slack times as well as when the shop is crowded with work.

Plan Ahead.—As soon as the drawings are completed, manufacturing information is prepared and sent to the shop, where it is kept until the work is done. This information includes all the paper work that is required by the various shop sections. It includes requisitions to order material either from the outside or from a store room and requisitions to machine individual parts and to assemble them after machining. A card for operation 6 is shown in Fig. 113.

This information is passed from the information clerk to the schedule clerk, who adds the date to each requisition when the material or labor as covered by that requisition is to be completed. Next the information passes to the time-study department where the list of operations required, with the time value for each, is added. After the time values have been added, the information is complete and is ready to be duplicated and distributed. Copies are made as required for the production, time-study, and cost departments. Each original requisition

is duplicated with a timecard for each operation listed. The card for each succeeding operation is marked with a number corresponding to the operation covered by that card. A column on the requisition gives the number of the shop machine tool that is to do the work. In cases where there are several machines that may do the same work, they list the type of machine instead of the actual number.

Time cards are separated and filed in order of date wanted in a box indexed for the operation shown on the card. There is a

ORDER NO.	G O ITEM	ASSIGNED ITEM	REQ FOR SECTION	DEL. TO SECTION	DATE WANTED	DWG. & SUB. OR STYLE NO.	ITEM
Sample		100 A	B1	B3	6/16	00-A-000	

QUANTITY	DWG. AND SUB	ITEM	STYLE OR PATTERN	DATE PROMISED
1	00-A-000	1		

NAME OF PIECE Frame — PROC. OR FINISH

MATERIAL FOR ONE PIECE

NOTES TAKE MATERIAL FROM MPI 6/7 AND MACHINE 6

CUSTOMER — CUSTOMER'S ORDER

PROD CLERK	WRITTEN BY	SECTION	DATE	TIME	ORDER SERVICE REP
		2 N	5/13		

WORKMAN'S NAME	SECTION	GROUP NO	CHECK	DATE	DWG. & SUB OR STYLE NO.	ITEM

MATERIAL REQ'D FOR ORDER · P.D. SPEC. · NET AREA · RATIO · NET WT. EACH · MAT'L PRICE · SCRAP CREDIT · MAT'L COST · LABOR & O.H. COST · FACTORY COST F.A. LB. · COST DEPT. NOTES

OPER. NO	TOOL NO.	MANUFACTURING OPERATION	SECTION	GROUP OR CK NO.	PIECES APPROVED	STANDARD TIME SET-UP	STANDARD TIME RUN. TIME	STD. COST RATE	INSPECTOR'S SIGNATURE
1	30258	Bore & face					18.00		
2	4058	Plane base					9.00		
3	Hand	Layout base & ends					4.50		
4	41299	Drill base				0.46	1.00		
5	41299	Drill & tap ends				0.25	5.25		
6	2990	Cut slots				1.25	10.00		
7	Hand	File burrs & clean					1.25		

Allowed hours represented by this operation 11.25

FIG. 113.—Copies are made of each requisition for each operation required. This copy is for operation 6 and should be filed in the control box behind the spacer for machine 2990.

separate file for each work group, machine, or group of machines. In a machining section there might be a separate file for a radial drill press, 60- and 72-in. vertical boring mills, 10-ft. vertical boring mills, turret lathes, engine lathes, welder, chip and file, and other necessary operations. Each spacer has a tab upon which is written the machine number or group number. Only machines that can do the same work are grouped together. After the time slips have been sorted by machines, there is a complete file of the work ahead of each machine in the order of date wanted.

In the lower right-hand corner of each timecard is placed the total time represented by the operation shown on that card. This time is the number of pieces called for on the order multiplied

Allowed Hours Loading

Section B-1 Cost center 112–113. Dispatcher West Date: 6–4–38

Capacity
Allowed hours per week, Eff 110%

Group of Mach	Operation	Date: Up to 6/4	6/5 to 6/11	6/12 to 6/18	6/19 to 6/25	6/26 to 7/2	7/3 to 7/9	7/10 to 7/16	7/17 to 7/23	7/24 to 7/30	7/31 to 8/6	8/7 to 8/13	8/14 to 8/20	8/21 to 8/27	8/28 up	Total	Present shifts	2 shifts	3 shifts
1	Boring mill 16 ft	80	210	160	130	160	170	300	150	130	180	90	60	110	300	2 230	176	176	264
2	Boring mill 14 ft		40	110	120	70	110	80	50	70		20	40		110	820	88	88	132
3	Boring mill 10 ft	20	80	80	120	40	110	45	95	110			20	10	160	890	88	88	132
4	Boring mill 6 ft	50	60	80	45	80	120	80	30	60	20		10		90	725	44	88	132
5	Planer 14 ft	110	60	30	20	50	40	30	45	35	20				20	460	44	88	132
6	Planer 10 ft	30	40	30	25	15	45	30	20			10	15			260	44	88	132
7	Planer 6 ft		10	110	40	30	45	30	15	10				10	45	345	88	88	132
8	Dovetail mill															0	44	88	132
9	50° dia grinder															0	44	88	132
10	Post mill		40	135	105	65	90			65	80	40			90	710	88	176	264
11	Drilling machine		20	50	20	10						40			30	170	44	88	132
12	Radial drill press	240	200	360	180	150	220	100	60	80	40				690	2 320	220	264	396
13	Keyseater		20	35	10	25					20				95	205	44	88	132
14	Layout	75	60	85	40	35	50	20	10	15	10				40	440	88		
15	Helpers and chippers	110	75	55	70	60	50	40	20	30	10	15	20	10	75	640	88		
	Total	715	915	1320	925	790	1050									10 215	1 232		

The above allowed hours include 20 per cent allowance for extra work

Fig 114.—Load charts made up at frequent intervals for use by work dispatchers and supervisors aid in maintaining proper control over the work going through the department These charts should be made up with sufficient frequency so that work will not come into the section and be shipped out between chart dates

by the allowed time per piece, plus the setup time. In order to determine the actual load ahead, it is necessary only to add up the time values on the cards in file. It is desirable to add the hours ahead of each machine for each week in the future. This can very easily be done each week or two as desired. The time between loading charts will depend upon the type of work being done, that is, whether the dates are long or short. If the turnover is rapid, it will be necessary to make the loading charts more often. The charts should be made often enough so that work will not come into the section and be shipped out between the times that charts are made.

After the allowed hours ahead have been added for each machine, the information is placed on a chart such as that shown in Fig. 114. In the example section the timecards are divided into 15 groups, and this chart represents conditions in the section as of June 4, 1938. The first column, marked "Up to 6/4" shows the hours that are overdue; these represent work that should have been completed prior to 6/4. The hours in the column marked 6/4 to 6/11 represent the hours ahead of each machine for that week and so on across the sheet. The allowed hours on the chart are allowed hours actually in file plus a percentage to cover the unforeseen operations, repairing defective work and other lost time that can be expected. The percentage to be added is obtained from the past history of the section. In this particular case 20 per cent is added.

Show Actual Capacity.—In order to use this chart properly, it must show the actual capacity in allowed hours for each group. It is convenient to show three capacities on the chart:

1. Present shifts, which are the allowed hours for work that could be done with each man on the pay roll working full time. These men may be working on first, second, or third shifts. From the example it can be seen that some machines are working one shift while others are running two or three shifts.

2. The capacity with each machine operated two full shifts.

3. With all of the machines operating three shifts or 24 hr. per day each. In this way it is possible to tell at a glance just how the various machines are loaded and to determine when it is necessary to add or take off a shift.

Since time values are in allowed hours and not elapsed hours, it is necessary to consider the efficiency of the section or machines

in determining the capacity. With an efficiency of 110 per cent, a workman will perform 44 allowed hours of work in 40 elapsed hours.

This information also is valuable to the supervisors in planning work ahead. It shows how many people will be required to do the work and will show when it is necessary to add or take off shifts. In a factory where the budget is set up to vary with the shop load or productive hours, the supervisors may determine what percentage of capacity to expect for the next few weeks, and thus will be able to exercise better control over budget expenditures.

Also, this information is helpful in determining the need for additional machines or, in some cases, may show an overcapacity. When this is the case, it may be possible to move machines to other sections.

PROCESS CHARTS

The process chart originated by the late Frank B. Gilbreth offers an excellent method of studying the routing of work through a shop. Allan H. Mogensen in *Factory, Management and Maintenance* points out its application in connection with making a receiver for a rifle. He first shows a process chart with the old machine layout, Fig. 115, with each operation listed and the travel in feet between each position in the shop. This totals 7547 ft. The chart uses some of the Gilbreth symbols which are explained at the bottom of Fig. 116, which also includes the summary of the comparison.

It will be noted that although only four operations have been saved, there is a saving in work travel of 6489 ft. Seven out of nine moves by the electric truck have been saved, amounting to 3504 ft, and hand-truck movements of over a mile have been eliminated. Manual movement of work has been greatly reduced: a conveyor has been installed, this added movement being offset by cutting out that of the elevator. This not only saves the time and labor of all this travel but has a decided effect on the maintenance of floors and the upkeep of the electric trucks.

Flow diagrams, drawn approximately to scale, will help in visualizing the distance traveled. Two such diagrams are shown in Figs. 117 and 118, the latter made after a new process

PROCESS FLOW CHART
MODEL 33 RECEIVER
OLD LAYOUT

TRAVEL (Feet)	OPERATION	DESCRIPTION:
	▽	Raw stores
	1	Load on truck
655		To dept 77
	2	Blank and pierce
27		To press
	3	Pierce 2 locating holes
24		To press
	4	First form
14		To press
	5	Second form
6		To press
	6	Finish form
20		To elevator 43-1
15		Up one floor
19		To wash
	7	Wash
57		To elevator
15		Up one floor
	▽	Wait for electric truck
1015		To dept 75
	8	Drill and assemble inserts
4		To floor
64		To riveting machine
	9	Rivet inserts
223		To bench
	10	Burr rivets and rear end
214		To handscrew machine
	11	C-bore and face front end
173		To wash room
	12	Wash
125		To drill
	13	Drill 3 holes
125		To wash
	14	Wash
64		To powermill
	15	Powermill loading opening
72		To wash
	16	Wash
211		To handmill
	17	Handmill recoil slot
93		To press
	18	Shave bolt lug slot
82		To profile
	19	Profile bolt slot
174		To wash
	20	Wash
335		To bench
	21	Finish file
251		To tapping machine
	22	Tap front end
66		To wash
	23	Wash
343		To bench
	[24]	Inspect
105		To elevator
15		Up one floor
172		To elevator
15		Up one floor
600		To polishing
	25	Polish outside
200		To bench
	26	Finish file
307		To bench
	[27]	Inspect
935		To dept 52
	28	Brown
171		To bench
	[29]	Inspect
10		To oil
	30	Oil
126		To elevator
45		Up 3 floors
120		To part stores
	▽	Part stores
240		To bench
	31	Assemble

FIG. 115.—Process chart with old machine layout.

PROCESS FLOW CHART
MODEL 33 RECEIVER
NEW LAYOUT

TRAVEL (Feet)	OPERATION	DESCRIPTION
	▽	Raw stores
150	Crane	To press
	1	Blank and pierce
10		To press
	2	Pierce 2 locating holes
10		To press
	3	First form
10		To press
	4	Second form
10		To press
	5	Finish form
323		To drill
	6	Drill and assemble rivets
18		To riveter
	7	Rivet inserts
2		To bench
	8	Burr rivets and rear end
14		To handscrew machine
	9	C-bore and face front end
30		To wash tank
	10	Wash
24		To drill
	11	Drill 3 holes
14		To lathe
	12	Line ream 3 holes
16		To powermill
	13	Powermill loading opening
18		To handmill
	14	Handmill recoil slot
4		To press
	15	Shave bolt lug slot
6		To profile
	16	Profile bolt slot
10		To wash
	17	Wash
8		To bench
	18	Finish file
16		To tapping machine
	19	Tap front end
8		To wash
	20	Wash
4		To bench
	[21]	Inspect
8		To jack
	22	Polish
3		To press
	23	Stamp number
18		To bench
	24	Finish corner and inspect
208		To brown
	25	Brown
20		To bench
	[26]	Inspect
80		To assembly
	▽	Before assembly
	27	Assemble

SUMMARY

	Old		New		Dif	
Total oper	31		27		4	
Total trav (Ft)	7547		1058		6489	
Total moves	No	Dist	No	Dist	No	Dist
By elec truck (K)	9	4036	2	531	7	3504
By hand truck (H)	22	3250'		–	22	3250'
By man (M)	6	157	23	427'	17	270
By conveyor (C)	–	–	1	100'	1	100'
By elevator (E)	5	105'	–	–	5	105'

○ Denotes an operation
o Denotes a transportation
▼ Denotes a temporary storage
▽ Denotes a permanent storage
□ Denotes an inspection

FIG. 116.—This shows a saving in work travel of 6489 ft.

chart had been made by rearrangement of machines. Process charts and flow diagrams should be made for each part of the machine and should show each step of the work as it goes through the shop.

Other Uses of Process Charts.—Process charts can also be made to follow the operator instead of the part or product. Such charts may be used for a number of different items.

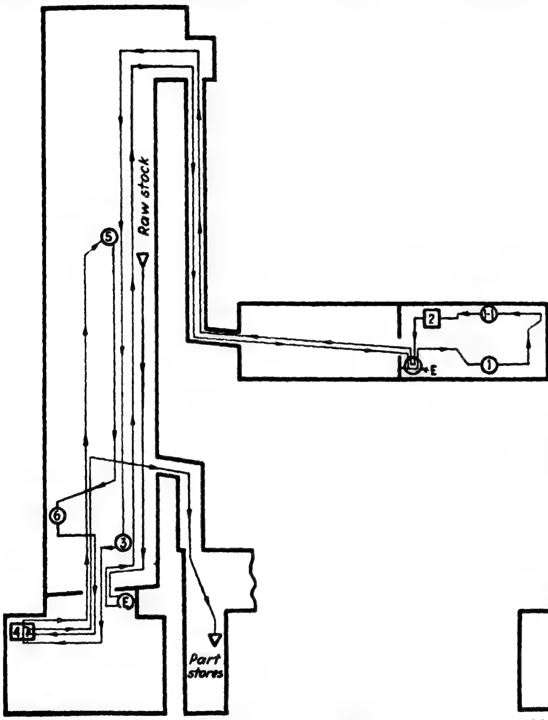


FIG. 117.—The original route of work travel.

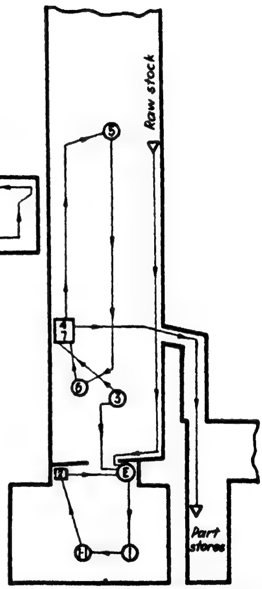


FIG. 118.—Note the shortened work travel and the elimination of the building in the center.

Some consider it advisable to make operator charts to check against machine layouts before deciding on the exact grouping of machines. It is sometimes advisable to check a given part by noting actual time for each of the operations and movements from start to finish. Comparing this with the previous records may show interesting discrepancies. It may show that while the actual time of operations is a matter of hours, delays at storage points may lengthen this into days.

Some users of this chart occasionally send through an order "extra-special rush" in order to see how this compares with the average time. While this may not be a fair comparison with standard time, it gives a mark to shoot at in regular work. The actual cost of these rush orders should be checked against standard costs before intimating that this might become regular practice if everyone was on his toes.

Charts or other studies of this kind are incentives to consider each operation carefully. Such questions as is it necessary, can it be combined with some other operation, can it be simplified, or will a different sequence be better, can be asked at every step.

CHECKING JOB SETUPS

Bright and early every Monday morning, inspectors in one large job shop meet as a group for carefully planned instruction in inspection procedure, standards of quality, trade customs, and like topics. In this plant, care is taken to be sure that best procedure, once developed and set down, does not merely become part of the archives of the business.

Like all others, this business is different. It really is peculiar in that a great many details may be involved in the necessary specifications for its iron and steel wire and its wire products. This does not mean that there is a great mass of detail in every job, but in the aggregate, there are enough details to warrant a rigid system for their control. Observance of the system is important enough to require accepted standard practices, further, procedure control is sufficiently important to justify standard instructions.

Each man attending the weekly instructional meeting has a folder containing not only his own, but all related, instructions. Thus, each man knows his own job and is familiar enough with those of draftsmen and associated inspectors to know what to expect in the line of job information, as well as to be able to substitute on other inspection jobs as occasion may demand. A carefully detailed organization chart keeps men from interfering with each other in the performance of duties. Taking a tip from the educational institutions, constant review, thorough quizzing, and the discussion of actual cases keep instructions fresh in mind and up to date. In this way it is possible to avoid having instructions followed simply because they are instructions,

without regard to who prepared them or the circumstances under which they were formulated.

TABLE 10.—STANDARD INSTRUCTIONS FOR CHECKING SETUPS

1. Assemble, check, and evaluate all component parts for the manufacturing specifications for the job:
   a. Read order and all change notices and notes.
   b Examine blueprint.
   c. Examine customer's sample, if any.
   d. Look over working parts or test jigs, if any.
   e. Examine approved samples, if any.
   f. Examine samples from past production when available.
   g. See that gages are used.
   h. Read over notes on previous orders if necessary to clarify doubtful points.
   i. Trace out any discrepancies with engineering department.
2. Compare parts with specifications:
   a. Material—check for kind, size, shape, finish, and temper.
   b. Type— Examine parts for quality of type.
      (1) Note functional requirements.
      (2) Note symmetry and forming.
      (3) Check with mill standards when necessary.
   c. Dimensions—Check.
      (1) See that size is near enough to normal so that machine will have sufficient running variation.
      (2) See that starting size allows greatest possible tool wear.
   d. Finish—Examine.
      (1) See if tool marks are disfiguring, or if they will be so after a short run.
      (2) See that finish meets the commercial requirements of the job.
      (3) Compare with standard samples, if necessary.
   e. Check with previous and subsequent operations, if any.
3. Notify foreman to make necessary changes or to proceed with production if O.K.
4. Make out specification change blanks to be approved by chief inspector and send to engineering department if any corrections or additions are necessary.

The process inspector has the triple responsibility of promoting economical manufacture by preventing further work on defective parts, of eliminating excessive spoilage, and of protecting the customer's interests as to quality. He ensures that only best raw materials are used and that work is started right. As it becomes increasingly important to supply customers on short notice, the importance of starting jobs correctly also increases. It is vital that process inspectors understand their products

thoroughly, be familiar with the machines that produce them, and retain the good will of the foreman and operators with whom they come in contact.

We find that the process inspector's success in fulfilling his responsibilities, while keeping the operators' good will, depends largely upon his ability to dispatch the checking of various jobs brought to his attention. Skeleton standard instructions, as presented in the Table 10, have been drawn up to aid him.

In order to discharge his responsibilities completely in a minimum of time, the inspector must proceed according to a definite inclusive plan. He must first study his requirements or specifications. He must assemble all elements of any set of specifications ordinarily furnished to the shop and must check them. He must concentrate only on important points, although to avoid further work on defective parts he must inspect according to the sequence of operations.

Comparison, the second phase of the job, is outlined by the four key words: *material, type, dimensions,* and *finish.* Knowing the customer's requirements, he checks the material. If it is not correct, no work is started. Consideration of general conformance to type and implied trade standards precedes his going into detail. When detail dimensions are checked, he turns his attention to the finish required. When the job is complete, he makes his report. It is only by following some schedule similar to this one that expeditious checking may be done. With detail changes to suit any particular business, the outline here reproduced can be adopted profitably by many plants.

CHAPTER 7

ESTIMATING

Success or failure in any kind of contract work depends upon careful and accurate estimates of the amount of material, the labor cost, and the overhead with a fair allowance for unforeseen contingencies. When competition is keen, the successful bidder is very apt to ask himself the old question, "What did I forget?" on the assumption that, as he was the low bidder, he must have overlooked one or more items of cost.

On the other hand, men who are experienced in placing contracts have good reason to be wary of a bid that is much below the average. Such bids usually result from inexperience on the part of the bidder. But sometimes the low bidder counts on being able to substitute cheaper material or a lower grade of workmanship for that specified. Then too, some count on being able to put in "extras" to make up for the low bid.

Low bids are not always cheap. Unless the bidder has a good reputation, he may quit the contract and leave the buyer in the lurch on needed material. It is really just as important to the buyer to have the contractor make a fair profit as to make one himself. For if ignorant or unscrupulous bids prevent the contractor from making a living, his source of supply may be endangered. Reliability on the part of your supplier should be carefully considered before turning down a bid in favor of some fly-by-night concern because it seems to save a few dollars.

The suggestions that follow should be of value in making estimates of various kinds as they represent the experience of men who have been successful in various parts of the country. Although they may not fit all cases, they will form a basis on which to gain experience in your particular field.

PRODUCTION ESTIMATES IN A SMALL SHOP

Here is a simple system used by P. P. Fenaux in estimating on orders for a shop of about 100 men and making various classes of

machinery. The selling prices of the machines were used as the basis of calculation.

No elaborate card system was used, all time and material being charged to each job number.

Assuming that an order was received for 25 sewing machines sold through a commission house for $1000 each and 6 grooving machines sold directly to the user at $400 each. The sewing machines are new to the shop, but the latter machines are duplicates of a previous order. The selling prices had been determined through experience or comparisons with competitors' prices and with no scientific cost figuring.

As there was a 15 per cent commission to pay on the sewing machines, the actual selling price was $850 each. These required new patterns which cost $1500, or $60 per machine, but there was no overhead expense on these. This leaves $790 per machine to pay for labor, material, overhead, and profit. Barring errors or accidents, the shop profit was considered as 25 per cent.

Deducting $198 as profit leaves $592 for actual expenses and overhead. Overhead was charged on material to take care of spoiled work and clerical expense, although this is sometimes not considered a legitimate charge. The overhead was figured at 40 per cent, leaving $\frac{592 \times 100}{140}$ or approximately $350 for material and actual labor expense. Allowing $25 as the cost of material for each machine leaves $325 for labor on each machine or $8125 for the 25 machines. At $30 per week this would pay one man for 270 weeks, in which time he would have to build the 25 machines to come within the estimate. Or 10 men would take 27 weeks, 27 men 10 weeks, and so on.

Following the same reasoning with the grooving machines, we can omit the pattern expense as these are duplicates of a former order. It was found that he made 35 per cent on the first order. Deducting the profit, or $140, leaves $260 as the actual expense and overhead. Deducting overhead of 40 per cent leaves $185 as the actual expense on each machine. Since the material of the previous machines cost $12 each, $173 is left for labor, or $5\frac{1}{2}$ weeks' work for each machine or 33 weeks for the lot of six machines.

The production chart, Fig. 119, shows just how each job stands in the shop. Each job goes through as a unit in charge of one

man who gets what helpers he needs as he needs them. The left-hand figures show the number of men working on the jobs. The vertical columns are weeks, and the shaded areas show the three jobs assigned to the three gangs.

Suppose the sewing machines are promised for June 1 and the grooving machines not later than the middle of May. The chart shows that Job 231 will take 15 men until the middle of April. Job 235 will take 25 men until the second week in March. Job 237, taking 10 men 7 weeks, is sandwiched in during March and April.

Job 236 takes 20 men 11 weeks. Job 238 takes men from Job 235 on the second week in March, from Job 231 in the middle of

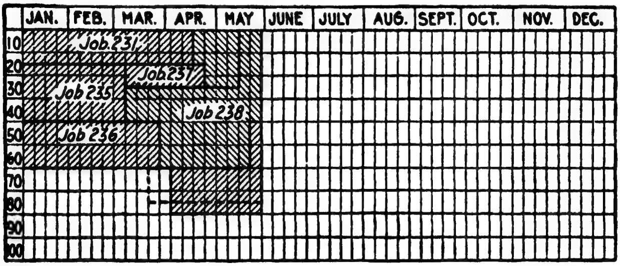


Fig. 119.—One way of making a production chart.

April, and from Job 236 at the end of March. It also shows that during April and May extra men must be hired to complete the contract by June 1.

If we read it another way it shows that the 25 men on Job 235 will be free at the end of the first week in March. Ten of these were assigned to Job 237 for 7 weeks; the rest went on Job 238. Such a chart enables the foreman or superintendent to see what capacity he has available and prevents making promises of delivery that cannot possibly be met. While not absolutely accurate, the chart proved very helpful in this small shop.

MACHINABILITY AND PIECE RATES

A study of the machinability of different steels and the effect on setting piece rates was made by James Sorenson, chief metallurgist, and Wallace Gates, head of the standards department, of the Four Wheel Drive Auto Company, and outlined in the *American Machinist.*[1] Their findings and the use to which they

[1] November 1, 1938.

put the information so secured may prove of value in many other shops. Their findings are abstracted in the following paragraphs.

Machinability ratings are valuable guides in selecting materials from a cost standpoint; they have a very practical application in setting rates or standards for machining operations; and they can be used when estimating machining times for new jobs or proposals. Usually there is no data available on which the machining qualities of a given steel can be judged.

Determining Rates for Steel.—The principal factors to be considered in determining the rate at which various steels can be machined are ductility, strength, and the effect of *ferrite* in steels having less than 0.30 per cent carbon. Ductility, as indicated by per cent elongation, controls the extent to which the chips will cling to the tool. Strength of the steel, as indicated by tensile or hardness values, affects the power required to thrust the cutting tool under the chip. Low ductility means less interference because of chips "balling up" in the tool, while low tensile strength will indicate that less power input will be required.

In steels below 0.30 per cent carbon, where the sulphur and phosphorus contents are below 0.06 and 0.05 per cent, respectively, and where no other element, such as lead, has been added to give free-machining properties, the soft, ductile ferrite is a sticky, gummy constituent which is difficult to cut. The amount of the free-ferrite constituent increases with decreasing carbon content. Hence, the effect of chips balling up on the tool and causing the material to tear, thus increasing the difficulty of obtaining a good surface finish, will increase as the carbon content is lowered in low-carbon steels.

Based on this reasoning and using standard test pieces of several steels of known composition and physical characteristics, a tentative range of machinability ratings was established. These were checked against several years of actual production experience on a wide variety of work, using 18-4-1 high-speed-steel tools and average machine-tool equipment. The results shown in Table 11 are set up with S.A.E. 1112 free-cutting Bessemer steel representing 100 per cent machinability.

Since these results are based on the average amount of material removed in normal production, no correction need be made in

these relative machinability values for cutting lubricant, operator, or other variable or unknown factors. The relative machinability ratings indicate results which should be obtainable in the average shop.

TABLE 11.—MACHINABILITY NUMBERS

Per cent	Number	Per cent	Number	Per cent	Number
97–102	46	58–60	35	35–36	24
93–96	45	56–57	34	34	23
89–92	44	54–55	33	32–33	22
84–88	43	51–53	32	31	21
81–83	42	49–50	31	29–30	20
77–80	41	47–48	30	28	19
74–76	40	45–46	29	27	18
71–73	39	43–44	28	26	17
67–70	38	41–42	27	25	16
64–66	37	39–40	26	24	15
61–63	36	37–38	25	22–23	14

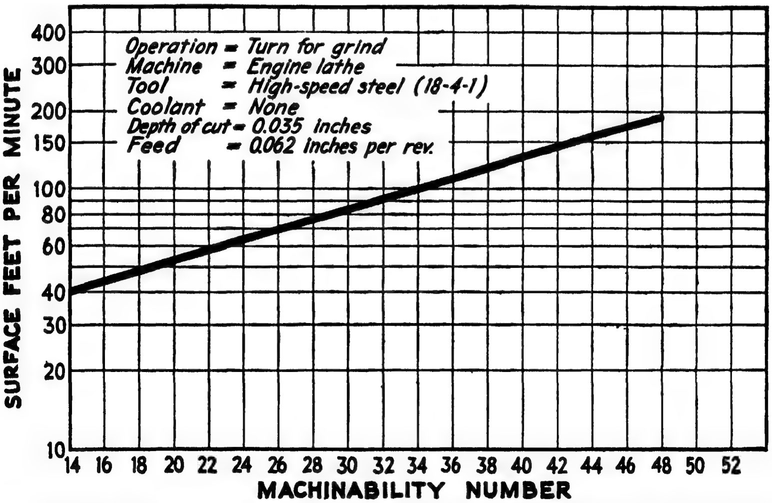


FIG. 120.—Surface speeds for turning metals with various machinability ratings are indicated above for a semifinish-turning operation under standard conditions in an engine lathe.

There are several ways in which these ratings may be used to determine machining allowances or standards. The method used at the Four Wheel Drive Auto Company is shown by the

curves in Fig. 120. For convenience, they have established a system of machinability numbers in which each number represents a material which is rated as five per cent more or less machinable than the next number below or above, respectively. These rating numbers were set up by having the number 46 represent 100 per cent machinability and assigning successive numbers. The complete list is given in Table 12.

With the machinability table at hand, it is not necessary to make a great many feed-speed tests on each type of operation to

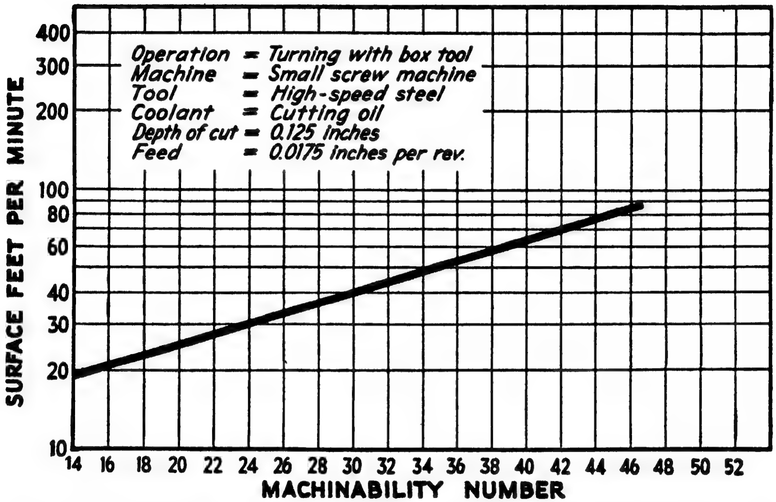


FIG. 121.—This chart shows the relation between the machinability number and surface speed when turning with a box tool in a small screw machine.

obtain a complete coverage of all the materials that may be run on a particular type of operation. It is only necessary to spot-check experimentally the speeds and feeds on one or two materials, establish the relation between feeds and depths of cut, and, remembering that machinability is an index to metal removal, determine graphically proper speeds and feeds for the other materials.

For example, Fig. 120 shows the relation between surface speed in feet per minute and machinability for semifinish-turning on an engine lathe that uses a high-speed-steel tool with no coolant at 0.035 in. depth of cut and 0.062 in. feed per revolution. With this curve machining times can be readily calculated for various

Table 12.—Relative Machinability of S.A.E. Steels

S.A.E. specifications	Process of manufacture	How finish-rolled	Treatment	Brinell hardness	Per cent machinability	Machinability number
Straight Carbon Steels						
1010	O.H.	Cold	No	124	50	31
1010	O.H	Hot	No	109	44	28
1020	O.H.	Cold	No	146	58	35
1020	O.H.	Hot	No	128	52	32
X1020	O.H.	Cold	No	165	68	38
X1020	O.H.	Hot	No	137	62	36
1030	O.H.	Cold	No	179	66	37
1030	O.H.	Hot	Ann.	149	65	37
1030	O.H.	Hot	Yes	192	58	35
1035	O.H.	Cold	No	183	64	37
1035	O.H.	Hot	Ann.	163	64	37
1035	O.H.	Hot	Yes	212	50	31
1040	O.H.	Cold	No	207	62	36
1040	O.H	Hot	Ann.	179	63	36
1040	O.H.	Hot	Yes	235	47	30
X1040	O.H.	Cold	No	212	60	35
X1040	O.H.	Hot	Ann.	185	62	36
X1040	O.H.	Hot	Yes	241	45	29
1095	O.H.	Hot	Ann.	207	43	28
Nickel Steels						
2315	O.H.	Cold	No	187	50	31
2315	O.H.	Hot	Ann.	159	51	32
2315	O.H.	Hot	Yes	228	46	29
2320	O H.	Cold	No	202	52	32
2320	O.H.	Hot	Ann.	166	54	33
2320	O.H.	Hot	Yes	235	45	29
2330	O.H.	Cold	No	223	48	30
2330	O.H.	Hot	Ann.	179	56	34
2330	O.H.	Hot	Yes	285	33	22
2340	O.H.	Cold	No	235	46	29
2340	O.H.	Hot	Ann.	201	51	32
2340	O.H.	Hot	Yes	302	28	19
2350	O.H.	Cold	No	293	39	26
2350	O.H.	Hot	Ann.	217	45	29
2350	O.H.	Hot	Yes	321	23	14
2515	O.H.	Cold	No	235	45	29
2515	O.H.	Hot	Ann.	163	42	27
2515	O.H.	Hot	Yes	241	35	24
Low Chrome-nickel Steels						
3120	O.H	Cold	No	201	54	33
3120	O.H	Hot	Ann.	146	58	35
3120	O.H.	Hot	Yes	235	45	29
3130	O.H.	Cold	No	223	52	32
3130	O.H.	Hot	Ann.	197	56	34
3130	O.H.	Hot	Yes	255	42	27
3140	O.H.	Cold	No	235	50	31
3140	O.H.	Hot	Ann.	207	55	33
3140	O.H.	Hot	Yes	286	37	25
X3140	O.H.	Cold	No	241	50	31
Medium Chrome-nickel Steels						
3220	O.H.	Cold	No	207	50	31
3220	O.H.	Hot	Ann.	185	52	32
3220	O.H.	Hot	Yes	255	40	26
3230	O.H.	Cold	No	235	47	30
3230	O.H.	Hot	Ann.	207	50	31
3230	O.H.	Hot	Yes	277	35	24
3240	O.H.	Cold	No	248	41	27
3240	O.H.	Hot	Ann.	212	43	28
3240	O.H.	Hot	Yes	285	32	22
3250	O.H.	Hot	Ann.	228	40	26
3250	O.H.	Hot	Yes	302	29	20
High Chrome-nickel Steels						
3312	O.H.	Hot	No	241	44	28
3312	O.H.	Hot	Ann.	192	48	30
3312	O.H.	Hot	Yes	277	40	26
3340	O.H.	Hot	Ann.	228	41	27
3340	O.H.	Hot	Yes	302	26	17
Chrome nickel-moly Steel						
4340	Elec.	Hot	Ann.	228	55	33
4340	Elec.	Hot	Yes	255	42	27
4340	Elec.	Hot	Yes	293	39	26
4340	Elec.	Hot	Yes	331	36	24
4340	Elec.	Hot	Yes	375	26	17
Nickel-moly Steels						
4615	O.H.	Cold	No	197	64	37
4615	O.H.	Hot	Ann.	149	62	36
4615	O.H.	Hot	Yes	235	54	33
4620	O.H.	Cold	No	207	66	37
4620	O H.	Hot	Ann.	163	64	37
4620	O.H.	Hot	Yes	248	52	32
4640	O H.	Hot	Ann.	207	60	35
4640	O.H	Hot	Yes	293	44	28
4640	O.H.	Hot	Yes	321	39	25
Chrome-moly Steels						
4130	O H.	Cold	No	212	56	34
4130	O H.	Hot	Ann.	179	58	35
4130	O.H	Hot	Yes	277	40	26
4140	O.H.	Cold	No	248	52	32
4140	O.H.	Hot	Ann.	183	55	33
4140	O.H.	Hot	Yes	285	38	25
4150	O.H.	Cold	No	269	46	29
4150	O H.	Hot	Ann.	197	52	32
4150	O.H.	Hot	Yes	302	34	23
Chrome Steels						
5140	O.H	Hot	Ann.	207	50	31
5140	O H.	Hot	Yes	269	38	25
52100	O.H.	Hot	Ann.	228	35	24
Chrome-vanadium Steels						
6120	O.H.	Cold	No	207	52	32
6120	O H.	Hot	Ann.	163	54	33
6120	O.H.	Hot	Yes	228	46	29
6130	O H.	Cold	No	228	54	33
6130	O H	Hot	Ann.	179	56	34
6130	O.H	Hot	Yes	277	35	24
6135	O H.	Cold	No	241	49	31
6135	O H.	Hot	Ann.	185	55	33
6135	O H.	Hot	Yes	286	33	22
6135	O H.	Hot	Yes	321	29	20
6140	O H.	Hot	Ann.	201	52	32
6150	O H.	Hot	Ann.	207	47	30
Silicon-manganese Steels						
9255	O H.	Hot	Ann.	224	40	26
9260	O.H.	Hot	Ann.	235	35	24
Free-cutting Steels						
1112	Bess.	Cold	No	174	100	46
1120	O.H.	Cold	No	165	82	42
1120	O.H.	Hot	No	137	76	40
X1315	O H	Cold	No	170	94	45
X1315	O.H.	Hot	No	149	88	43
X1335	O.H.	Cold	No	212	65	37
X1335	O.H.	Hot	Ann.	201	60	35

Note: In columns headed "Treatment," "Ann." means annealed; "No" means no heat-treatment or as rolled; "Yes" means heat-treat, quench, and draw. Machinability ratings and Brinell hardness values should not be considered as absolute, but rather as guides to what can be accomplished with average fabricating equipment. This table is intended primarily for use in connection with high-speed-steel (18-4-1) cutting tools.

lengths of cut in various materials. Feed must be varied for the different depths of cut and for different finishes.

Figure 121 is for turning with a box tool on a small screw machine. Three hours' actual cutting time is the standard tool life for these values. Figure 122 shows another variation where machinability numbers are plotted against the time required to drill a center hole. This deals with a condition where many factors are constant. The hand-fed centering drill was used in drilling a constant-size center hole, and the machine had a fixed

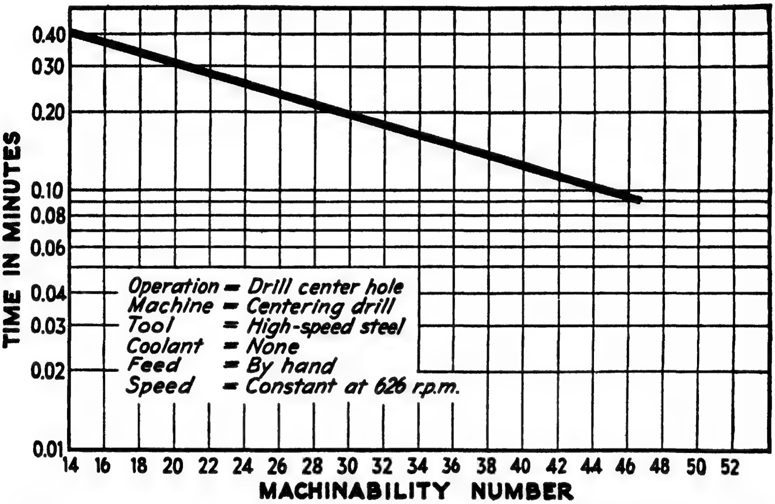


FIG. 122.—Time required for drilling a center hole can be determined directly, as most of the factors involved are constant.

or constant r.p.m. Since all these conditions are constant, the time varies only with change in materials.

The machinability table was also applied to many other machining operations with considerable success. It must be remembered that the actual values of surface feet per minute and the time found in these examples, Figs. 120, 121, and 122, were proved accurate in one shop, but may have to be altered to fit conditions existing in other places. However, such adjustments can be made merely by raising or lowering the lines and keeping the slope constant.

For one group of machines the machinability table was used as a guide to relative amounts of power required to remove a given amount of metal per minute and, inversely, the relative

amount of metal that could be removed per minute with a given amount of power. This makes a valuable guide when setting rates or standards on a machine where the power available is a limiting factor on feeds and speeds.

After having determined and prepared machinability data of this sort, it is possible to calculate machining times and to establish standards or piece rates based on the type and the amount of metal to be removed for almost any machining operation. Curves of machinability number versus one of the three variables—surface speed, volume of metal removed, and time—can be established for nearly every machine in the shop after only a few check tests on each type of operation. Once they have been drawn up and arranged for ready reference, calculation of the machining portion of piece rates is a fairly simple operation.

Many shops have high-production jobs that are run on special- or heavy-duty machines where both the quantity and the nature of the operation warrant the use of tantalum carbide, tungsten carbide, or other special tools. With such tools very high surface speeds are obtainable and the machinability ratings are of little use. However, where shops work on small quantities and a large variety of jobs, and where high-speed steel cutting tools are used, a relative machinability table is most valuable.

Since the ratings have all been determined relative to production results on S.A.E. 1112 steel, the machinability percentages should not be much different for other shops. If the type of machine is different, or if the volume of metal removed in a given time is more or less, there should be only a shift in the base line, but no particular change in the relative machinability of the materials.

Some shop practices and methods may necessitate a change in some of the figures, but such changes should be small.

Tests.—Using standard test pieces of various steels of known composition and physical characteristics, and then checking the test results with several years' production experience on a wide variety of work, the following machinability ratings have been determined for S.A.E. steels. These results are based on the use of 18-4-1 high-speed-steel tools in average production-type machine tools. The relative per cent machinability rating has been set up with S.A.E. 1112 free-cutting Bessemer steel representing 100 per cent machinability.

Since they are based on metal removal in normal production work, no correction is necessary for changes in variable or unknown factors. The ratings represent results which should be obtained without difficulty in the average shop.

Machinability numbers assigned to the various steels are selected according to a method explained on the preceding pages. With these data it is necessary only to spot-check the feeds and speeds best suited for a given operation on one or two steels and then determine graphically the proper speeds and feeds for other steels on the list.

ESTIMATING ON CONTRACT WORK

A difficulty likely to be encountered by any shop that bids on a contract job is the lack of sufficient time for proper checking of material weights, and the time that will probably be consumed in the pattern shop and foundry and in getting material through the machine shop. This is very likely to be true of heavy work where it is important that weights be closely calculated.

Large-size castings, and particularly those with various ribs and odd contours, may be easily figured far out of the way and even with fairly close calculation. The pattern and foundry method may throw the original figures out of line with the estimator's ideas. Contracts have been bid on at too high a figure because of wrong estimates of weight. Consequently, the job was taken to another shop which was able to make a closer estimate.

Estimators.—Some concerns leave the work of estimating to a specialist in this line. With no further check on his figures there is a chance that he has allowed too much weight and based his costs upon too much metal, with the result that the job is lost to that particular shop. Then too, some firms follow a practice of adding a certain percentage "for safety's sake" to the original estimate, and this may also help toward throwing the work to another plant. Where two men check over presumable weights, there is a better chance of accuracy in the final figures on castings and forging weights.

Besides having an uncanny knowledge in the art of figuring material weights, the estimator should have equal skill in mentally "seeing" the job through the shop in advance of any actual

work. He must know the machine equipment available; must know the usual allowance of excess metal for finishing all sorts of work; and must have a pretty clear idea of just what the method will be of handling the job in the event that the firm lands the contract

Cost of Excess Stock.—How much must he allow in machining operations for removing excess stock? Depending upon the size and character of the castings, this allowance may range from $\frac{1}{8}$ to $\frac{1}{2}$ in., and on big work it is surprising how much metal there is to be removed from wide areas, bored out, or turned off. Pattern draft affects the matter also and the handling in the foundry provides another factor that cannot always be properly allowed for.

Beyond the problem of weights of castings comes the figuring of presumable time that will be required to machine the work. If heavy, as on much contract work, due allowance must be made for handling the job through the shop, in and out of machines, and for actual machining time. As with some other work, wide experience will be of first aid in providing the estimator with knowledge of average performance in that particular shop with similar undertakings.

Even then, each new job presents its own special problems so far as setting up and machining are concerned. Records of past performances will undoubtedly help greatly; but such factors as peculiarities of design or unusual requirements of finish may upset one's judgment as to the exact time likely to be consumed by the project.

This applies to the unusual type of work which frequently comes to the fair-sized jobbing shop for estimates on bids. Where much smaller parts and work to be duplicated in quantity are being considered, there is usually a chance to readjust the method of approach to the work in the shop and develop some more rapid method of handling a contract that might appear to be a losing one if carried out in the customary manner.

With regard to weights of cast materials, if we consider say a modest-sized dryer casting of 36 in. diameter by 60-in. face, we have approximately 1 in. of wall thickness, a metal weight of nearly 1 ton in the finished work. But if we add $\frac{3}{8}$ in. for finish on the outside all the way around (and something like this is usually necessary on such work), we have a surplus of metal

amounting to several hundred pounds, even under the best conditions. If to this we add more than necessary, we may scrap more material than the actual machining cost amounts to.

With steel castings the cost of excess finish allowance is even greater. Greater allowance is usually necessary anyway and then, too, the cost per pound is much higher, so that the estimator must apply considered judgment in arranging his presumable costs of materials.

Estimating from Blueprints.—It is remarkable, however, how closely experienced men can figure on such work from blueprints. Cases are known where castings weighing 25 or 30 tons have been calculated in advance by two men whose figures on weights checked within $\frac{1}{2}$ of 1 per cent.

But work of this size is not always done in large shops. Some small shops with perhaps 25 or more men are equipped for big work and make more or less a specialty of doing such jobs. The shop may have a large long bed lathe (and several normal-sized ones also); a big planer, probably with short bed; a horizontal floor-plate boring machine; and a vertical boring mill or two. The capacity is ample for doing big work as that term is generally understood.

Figuring weights cautiously is important also to shops handling small-contract business where large numbers of pieces are involved. Although ample material must be allowed for removing by lathe and planer tools and by milling cutters, excess allowance on smaller stuff will be detrimental when one comes to estimate the total tonnage of a large lot of pieces. This is especially true where brass and bronze or other copper or high-priced alloys are involved because of the high cost of the original castings. In spite of the fact that there is considerable salvage value in scrap and chips from such work, it is still desirable to hold down to a working minimum the allowance for machine and finishing.

"Working minimum" in this case means that amount which will enable the work to machine freely without undue dulling of tools, but at the same time allowing as little more as possible.

Naturally, the method under which a job will be machined has much to do with the problem; that is, it may be a straight lathe job where simple turning and chucking out of cored holes are all that will be required. But where surface finishing in addition,

by planing, shaping, or milling, will be necessary, adequate material allowance is called for over a considerable number of surfaces, and this means that one must understand something of the foundry practice in producing castings of the general character under consideration.

Overweight Castings.—Some foundries are known as producing work on the "heavy" side meaning they run to the safe side with ample metal for finishing work. Up to a certain point this is desirable practice for it is, after all, easier to machine an oversize casting than to fuss and readjust castings with too small allowance in order to finish all surfaces properly.

At the same time such oversize (heavy) castings are sometimes too large to enter jigs and fixtures properly, introducing another problem which involves special-tool design—where any such tools are to be built for a given job.

The usual shop of modest size does not have a pattern shop or foundry. It does however have access to different jobbing shops making patterns and castings and can thus use to advantage the results of their experience and facilities.

TIME UNITS IN PRODUCTION

In setting up production standards in units of time, these units are based upon a certain kind of workmanship or quality of work made under fixed tolerances which may be either close or quite free according to requirements. But in any case they are definite. Also the work is handled on equipment whose capacity as to output is a known quantity.

Assuming that the factors of speeds, feeds, and depth of cut are the only ones involved in making up the production time, it is then possible to compute values closely. However, it is something different to secure these results in actual working conditions. Still, these values do form a standard that production men can make an effort to reach.

By comparing actual time records of individual operations or cuts on a job with the calculations made for that particular set of operations, it is possible to find the points in the machining processes where the principal differences or discrepancies take place. When the shop management has located the spot where estimates and actualities draw apart, it can then apply itself to correcting such differences. It is often the case that computa-

tions have been cut too fine for average results. On the other hand the mere study concentrated on the particular operation in question cannot fail to lead to some improvement at least.

Group Operations.—In smaller shops on simpler production systems, particularly if the general line of work is more or less of similar character, they sometimes use a method where time studies are based upon group operations and work. This is true when operations are carried on over several different kinds of pieces of the same general kind and size. These may vary in length and diameter but resemble each other rather closely in the main. This applies more especially to such operations as are typical of turning jobs in the engine lathe and many common classes of turret lathe work. In the case of work performed on the milling machine and the shaper, any variation between different kinds of pieces in a group under time study would be considered simply upon comparison of surfaces of areas depending upon width and length of the work surface.

Assuming that the general arrangement of tools is alike on different jobs under consideration, the data obtained from such group studies can often be applied to various other classes of parts requiring much the same tool application and having practically comparable areas to be machined or, in the case of turned work, about the same weight of material to be removed in lathe or turret lathe.

When a piece of work is analyzed, the job is broken down into such elements as preparation of the piece for machine operations; type and number of cuts, sharpening and setting tools, and handling work in and out of the machine. The nature of the work in general, the type of shop, and the volume of work have a definite bearing upon the extent to which an analysis should be carried out. If runs of work are short or only of reasonable length, it is not feasible to split up every act and movement of men and machines in the process of handling the job. On the other hand, fairly small lots can be made the subjects of reasonable time studies if these are made with the idea of gleaning information and data rather than merely of compiling a lot of records that may not have special significance when the next job comes under observation. Such records should be of first aid in many cases, if suitably gathered, and arranged for the purpose, and used with discretion.

Note Past Performance.—Any individual in the planning department responsible for routing work and for computing the amount of time presumably necessary for doing the work can utilize any satisfactory collection of figures and general data on past performances of the plant. The various machining undertakings already passed through the shop should be in large measure the guide for setting up time estimates on new jobs coming along. Estimates on contracts can be made much more closely by records available from operations already accomplished which bear close resemblance in type of work and character of cut, for with similar pieces to handle and similar tooling and operations there should be close resemblance in results with regard to ultimate time necessary for putting the contract through the plant.

While close studies made with the stop watch are not usually practicable in the small shop on short runs, the longer production schedules of other plants do justify a concentrated effort for finely divided details of operation times. There the entire project can be analyzed step by step, including such details as handling materials in and out of stores and inspection departments as well as actually through certain stages in that department.

Where results obtained in machining operations fail to come up to estimated values based upon known production capacities of the tools, rechecking is required, and here the records of past accomplishments are of added value in helping to locate the discrepancies between estimated times and actual performances.

IMPORTANCE OF ASSEMBLY COSTS

Exact costs of assembly are sometimes ignored when one is estimating on special jobs. This is also true of estimates made on regular production work, and some modification is often necessary in figures compiled from advance estimates based on past performance on work of similar character. When the details of actual costs are later analyzed, it is often necessary to revise methods of assembly to offset errors in first estimates on the total shop costs.

Variation in Time.—The small shop—as well as the larger organization—is likely to allow too limited time and expense in assembling processes. There are various causes for this, but often it is caused by the fact that the detailed practice of the

machining departments is not taken into full consideration. For example, in some cases the work comes from different machines in proper condition for ease of assembly, whereas in other cases there may be too liberal manufacturing tolerance allowed so that some hand work and refinishing may be called for in putting certain parts together.

One cannot always judge by the finished value of a product how accurately its parts must be manufactured. It is a commonplace fact in specialty work that an inexpensive product cannot have too much time spent on assembling its parts. Consequently, some very cheap articles are composed of some very closely made parts in order that no time be wasted in the assembly department. An example might be cited of the corner posts in certain very cheap locks or similar items where shouldered pins or posts are to be set and riveted in the side plates after these are pierced in the punch press. If the fit is too sloppy, staking or riveting in assembling will take too much time, and the result will not be a neat piece of work. If the fit is too tight, there will be trouble in the opposite direction and time will be lost in entering the post preparatory to spinning the rivet. The allowance between pierced-hole and shoulder fit on the pin must be set at a suitable figure to start with and held to through the life of the job, within reasonable limits, otherwise delay will be found at the assembly bench.

Certain classes of mechanism, in business machines and other products, are largely built up of stamped parts and screw-machine items, and the costs of manufacturing such pieces are very low. But the assembling of much work of this kind is another matter and has only been made possible at a reasonable cost by the development of suitable fits at all points and the use of properly designed jigs and fixtures for aiding assembly.

Assembly Fixtures.—In addition to assembly fixtures, there are many devices for handling small parts easily; for clamping and releasing them in bench vises; for using foot treadles to operate bench fixtures, leaving both hands free; and other convenient appliances. These have been put to good use in different factories to facilitate the assembly processes.

Besides the use of such devices in specialty plants, the development of somewhat similar methods has taken place in larger work, such as that in aircraft plants. Also, in general welding of

many jobs on a production basis, special jigs have been designed for holding all elements while the welding is carried on. Fabrication of many lines of metal work has been advanced appreciably by the application of welding fixtures of the general type referred to.

In addition to the use of fixtures for assembly work there is occasion in small-parts assembly for the extension of bench trays, racks, and other details, whereby the operators can pick up without hunt-and-seek methods each piece in the order in which it should be placed in the growing unit. This arrangement is seen in such places as instrument shops and similar plants and has been developed to a marked extent in a number of places where assembly costs have been given close study.

The inspection department can do much to simplify the work of assembling. In some shops too much material is passed which will cause delay later on. Delay that results from the need for burring, filing, additional polishing, or some other finishing process is expensive when these operations fall on the crew at the assembling benches.

Shops have sometimes discovered that there was enough machine work being done by the assembly group to keep a small department busy. This has been improved by installing a special department for handling simple bench-machine jobs where burring, special reaming, buffing of certain pieces and other detail work could be carried on as a regular part of the production system without leaving anything of the kind to delay the assembly work when such parts came to the benches.

With special jobs where the extent of the contract is limited, complete organization of an adequate assembling system is out of the question. It must be recognized that this end of the project is likely to be much more expensive than it at first appears, and due allowance must be made for this situation. However, some simple tools and devices are usually possible for helping out in the work, and where the job is to run for some time, it is good policy to design a few appliances for aiding the men at the bench.

ESTIMATES ON SCREW-MACHINE WORK

Operation of screw-machine products shops or screw-machine departments in factories requires special methods of estimating on materials. Such work means allowing for more or less waste

of the bar material, steel, brass, and others. Ordinarily the cut-off tool has a width of $\frac{1}{8}$ in., but on larger work this width will be as much as $\frac{3}{16}$ in. Small stock may be cut off with $\frac{3}{32}$ or even thinner tools in some instances. Ordinarily the $\frac{1}{8}$ in. allowance is close enough for stock estimates.

This means that for each piece cut off from the rod, $\frac{1}{8}$ in. is wasted; and in work averaging $1\frac{1}{2}$ to $2\frac{1}{2}$ in. some 7 or 8 per cent of the total length of rod material is wasted in cut-off operations and at the end of the bar another 3 in. is lost because that length is required to grip and feed the rod through the spindle.

Taking 10-ft. lengths as common, the 3 in. wasted at the end are $2\frac{1}{2}$ per cent of the length, so that, all told, about 10 per cent extra stock must be included in figuring the total amount of material necessary for a given number of pieces in the job.

Short Pieces.—In the case of short work like thin washers, nut blanks, or other short pieces, the percentage of stock used in mere cutting off is as much as 20 per cent, or sometimes more, so that one must use care in estimating the total amount of material to be used in a run of this kind. Short collars, special disks, rings, and many other articles either plain or finished by some shape of forming tool fall into the general class of work where the man making estimates must be especially watchful of his figures.

In addition to this, there is the fact that a large percentage of the rod is machined away in finishing the article. The customer does not always realize that so large a part of the original stock weight is consumed in making chips, and he sometimes concludes from the slight weight of the finished piece that he is being overcharged on material. On this point, if one takes a cap screw $\frac{1}{2} \times 2$ in. long as made from a $\frac{3}{4}$-in. hex bar, he will find that fully one-half of the material has gone in the machining and cutting-off operations.

In spite of the fact that all turning and similar operations in the screw machine (like lathe work and other similar operations) cut away much material, the handling of screw-machine work is so economical and rapid that material going into chips is more than made up for by the speed and extreme accuracy of the work process.

Hand and Automatic Work.—The man who runs a shop doing this work will find that while small lots and medium runs of work

are commonly handled on hand and semi-automatic machines. There is always a chance for the specialty shop to keep among its automatics one or more that will be available at any time for moderate runs by limited changes of cams thereby eliminating the necessity of making entire sets for the job in hand. Changing collets and turret tools and possibly some camming will often answer for very economical runs even though production is not up to the limit that is possible with everything set for fastest runs.

The same is true of box tools and others. Whereas rapid production is obtained by combining tools in single holders and turret positions, plenty of short-run jobs can be handled effectively by simple application of plain tools without additional time for setting up for quicker results in the machine. This is in the case where the total time required for the run is quite short.

It is an important feature in this connection that after a shop has been running in this line for quite a while it has gathered together a considerable quantity of screw-machine tools, both turret and cross slide, which can often be picked up at once for a short run where complete sets of new tools would be unnecessary. Even on some long runs of work it is the case that tools may be at hand for rapid production without the expense of making new ones. In a slight degree this is true with some classes of forming tools, where an exact form is not essential but is more of a finish for the end, or for a shoulder on the piece.

Screw-machine Competitors.—Stamping, forging, swaging, and die casting today have taken over certain classes of work that formerly were in the screw-machine field. However, new articles come along to be made, and the larger capacities of the screw machine and its flexibility for manufacturing so many kinds of work without special dies or molds have extended its uses still further in the important fields of both big production and special-lot work.

Its low tool cost and low cost of operation give the screw machine advantages still unexcelled in its field. It is optional whether the screw machine shall finish in one operation the complete piece or leave certain rear-end operations for another process. The arrangement of the work depends upon how far one wishes to go to complete all cuts before the work is dropped out of the machine.

The wise manager with such work will divide the processes as seems best according to the equipment available in his shop. Each job is something to be considered by itself when second operations are under discussion.

Many sections of stock are available to help the shop, in respect to additions to round, square, and hexagonal bars. For example, pinion wire and other sections are ready for cutting off in the machine to suit small gear and other requirements at a minimum of expense and time.

Brass Screw-machine Work

In connection with cost estimates on screw-machine work it is well to note something of the rapidity with which brass work can be produced on either hand or automatic machines and also the relatively slight amount of wear on all classes of cutting tools produced by such operations as those carried on with free-cutting brass.

The ease with which such material can be machined in all classes of turret machines is well known, but it is not always appreciated that tools can be used with stock running at highest rates of speed and yet maintain satisfactory conditions for relatively long periods, thereby reducing appreciably the "down time" expended where frequent grinding of tools is necessary.

Also with most operations on screw machines, fairly rapid rates of feed are practicable, again cutting down production times. The freedom with which such brass is cut enables medium and larger work to be finished, even with hand turrets, with marked advantage. The important quality that enables free-cutting brass to be worked easily is not conspicuously advantageous on very small work where even hand operations are maintained without strain upon the part of the operator. When it comes to work of fairly large diameter and corresponding depths of cut and rates of feed, the character of the material and its ease of working are important factors in the day's output and in the effect upon hand operators.

On automatic screw machines, feed rates once set by the application of suitable cams remain constant throughout the run regardless of operators. But even here, the working qualities of free-cutting brass, including its relatively slight wearing effect on

turret tools and cross-slide tools, etc., has considerable influence on total costs.

Wear of Tools.—Cutting-tool wear is something to be taken under consideration in all classes of production machinery. The removing of drills, turning tools, forming tools, and the like is always a matter of lost time, particularly in the resetting processes. The extension of times between regrinding and resetting is important and also the grinding away of the tool itself is another item of shop expense leading to premature replacement of certain tools. As compared with most other materials, tool wear on free-cutting brass is usually extended appreciably. There is also freedom from breakage, and a further difficulty is offset by the manner in which chips from this material tend to break up and clear the tools without clogging or jamming.

Free-cutting brass contains a small percentage of lead. This aids its free-cutting properties and causes the chips to break away from the cutting tools. It is easier to hold work to required tolerances owing to reduced wear on tool edges and time is saved in this manner.

Producers of this material state that not only can maximum spindle speeds be used for automatic operations, but that cut-off tools can usually be held to thinner sections than commonly employed where harder or rougher material is machined. Where miscellaneous cutting off may be done with tools taking about 12 per cent or more of the stock in the length of a bar (on pieces of average length), this kind of brass can reduce total stock waste to about 8 or 10 per cent, assuming again that we are dealing with average lengths of work as turned out in automatics. The waste in cutting-off operations is always important. Any appreciable reduction that is possible is worth considering.

Selection of suitable material for a run of screw-machine work is often determined upon a pound price of materials. This may or may not be advantageous. As against the cheaper rod stock, the more expensive material will present a reduced machining time, and on long runs this shows up to advantage. Also the finish at high rates of turning and forming saves further processing or at least reduces such operations to a minimum and gives another advantage here.

In actual automatic machining, forming can usually be carried on at the same rate as smaller drilling operations, and the drop-

ping out of the finished piece is then not necessarily held back by the slower forming process, which is usual where harder stock is being worked.

Brass work as finished in the screw machine often requires nothing further in the way of a finish treatment. Surface finishes, when required, are ordinarily simple. On the other hand, there are many instances where the harder tougher materials are called for by conditions of usage, and there are plenty of such cases where brass of any kind is out of the question. The point to all the foregoing is, however, that first cost of rod stock should not be the determining factor if the shop has anything to say in reference to material to be selected for any given run of screw-machine work.

CHART FOR BAR STOCK CALCULATIONS

The chart by M. A. Markel in Fig. 123, which takes into consideration the conventional sizes of bar stock and parting tools, is designed to determine quickly (1) the number of pieces that can be cut from a single bar; (2) the number of pieces that can be cut from a given amount of bar stock; and (3) the amount of bar stock required for a given number of pieces. The waste or crop end of the bar, as necessitated by the length of the piece or the machine, can also be determined. Instructions for using the chart are given on page 283.

Examples

Case 1.—Parting-tool width = $\frac{3}{16}$ in.; piece length = $3\frac{1}{2}$ in.; bar length = 16 ft.; crop end = 8 in. By following instructions in the table, lines 1 and 3 are drawn vertically until they intersect the curves of the given piece length and bar length, respectively, that is, $3\frac{1}{2}$ in. and 16 ft. Lines 2 and 4 are drawn horizontally to intersect edges *A* and *E*, respectively, of the left-hand and right-hand vertical charts. The line from *A* to *E*, joining lines 2 and 4, intersects Scales *B*, *C*, and *D*, thus giving the number of pieces from one 16-ft. bar as 49.

Case 2.—Continuing the problem in Case 1, line 6 can be drawn through 1500 pieces on Scale *C*, for which it is found that 31 bars will be required.

Case 3.—Continuing with Case 1, assume 15 bars are available, line 7 can be drawn, giving 735 as the number of pieces which can

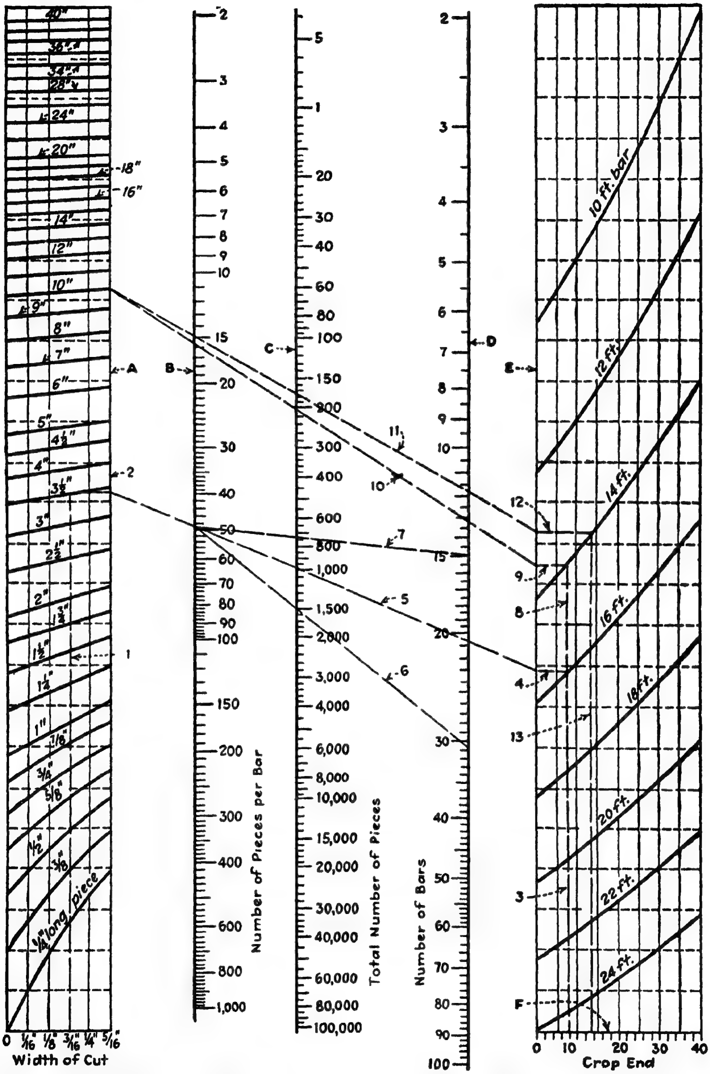


FIG. 123.—Chart for estimating bar stock. Instructions for use are given in Table 13 on the opposite page.

be obtained from the 15 bars; obviously, this can be obtained easily by simple multiplication.

The chart can be used in this manner where the piece length is shorter than the minimum crop end as determined by the machine chuck and stock feed. For pieces longer than the minimum crop end, line 5 has to intersect Scale *B* at the largest whole number that will give a crop end equal in length or somewhat larger than the given minimum. This is illustrated by the following analysis, which is Case 4 of the table, on page 284.

TABLE 13.—INSTRUCTIONS FOR USING THE CHART,* FIG. 123

Case	Given	Wanted	Draw connecting lines	Remarks
1	Tool width Piece length Crop end Bar length	Number of pieces per bar	1, 2, 3, 4, 5	These instructions for pieces shorter than minimum crop end as necessitated by the machine
2	Tool width Piece length Crop end Bar length No. of pieces	Number of bars	1, 2, 3, 4, 5, 6	
3	Tool width Piece length Crop end Bar length No. of bars	Total number of pieces	1, 2, 3, 4, 5, 7	
4	Tool width Piece length Min. crop Piece length No. of pieces	(*a*) Waste (*b*) Total number of bars	8, 9, 10, 11, 12, 13† (See Note below)	These instructions for pieces longer than minimum crop end; line 11 has to intersect the largest whole number on Scale *B* which gives a crop end equal to or greater than minimum crop

* Examples in the text exemplify the use of these instructions.

† Since a $\frac{1}{16}$-in. parting tool is used in this example, lines similar to 1 and 2 of case 1 need not be drawn.

NOTE. Lines drawn through Scales *B* and *C*, intersecting Scale *D*, will give the total number of bars required for a given number of pieces.

Case 4.—Parting-tool width = $\frac{5}{16}$ in.; piece length = 10 in.; minimum crop end = 8 in.; bar length = 14 ft. Find the number of pieces per bar, the length of waste, and the number of bars required for 700 pieces. By drawing lines 8, 9, and 10, similar to lines 3, 4, and 5 in Case 1, it is found that 15 pieces is the maximum number of pieces that can be cut from the 14-ft. bar; therefore, line 11 is drawn from Scale *A* through 15 on Scale *B* until it intersects Scale *E*. Line 12 is drawn horizontally until it intersects the curve for the 14-ft. bar. Line 13, dropped vertically to Scale *F*, gives the waste end as slightly under 14 in., that is, 13.3 in. by calculation. By drawing a line through 15 on Scale *B* and 700 on Scale *C*, it is found that 46+ or 47 bars are needed.

CHAPTER 8

APPRENTICESHIP AND TRAINING

The constant need for trained mechanics indicates that every shop should do its share in training boys and young men to carry on the work. For while machines are being made that can be run with operators of limited experience, both the building of these machines and their maintenance requires more skill than ever before. Without skilled mechanics to keep these intricate machines in running order, they would soon be useless. The semiskilled operators are usually unable to set the machines up for different jobs or to adjust or repair them when anything goes wrong.

APPRENTICE SCHOOLS

While it is of course impossible for small shops to establish and maintain regular apprentice schools, nearly all can do something in the way of training. In Davenport, Moline, and East Moline, Ill., the small shops clubbed together and, in connection with the chamber of commerce, have maintained a cooperative training school for over ten years. Boys are shifted from one shop to another to give them a greater variety of training than they could get in any one shop. Details of this school can be had from the chamber of commerce of either city and is well worth a study by small-shop owners in other localities.

Those who have conducted apprentice schools for many years find that it pays in dollars and cents as well as being a direct contribution to the welfare of their city and the country at large. In some cases, however, management looks on maintenance men as an expense instead of an asset. They see only the product from which they get their income directly. It too frequently happens that a comparatively unskilled boy or young man will earn more, by piecework and bonus, than the maintenance man gets for keeping the machines running. This leads boys to ask themselves why they should spend several years learning a trade

when a boy fresh off the farm can earn a fatter pay envelope in three months than the other gets after three or four years' training.

Maintenance men should be regarded as "stand-by" equipment, in somewhat the same way as we look at spare motors or machines, which cost money to buy and to store but prevent costly delays to production when a machine goes out of order—as they all do sooner or later. One good practice is to have maintenance men on a weekly or monthly basis and to treat them with consideration for the savings they make when a machine refuses to produce its quota. Skilled and reliable maintenance men are among the most important assets to any shop.

EMERGENCY TRAINING

The training of toolmakers or other good mechanics is not the serious problem many seem to think. Selection of boys or men, preferably—but not necessarily—under twenty-five, with strong mechanical leanings is the first step.

Next they must be taught the *fundamentals* of the business, either in good trade schools or in shop schools. The old idea that four years was necessary is a hangover from the past. Intensive instruction by competent teachers—instead of making the boys sweep the shop, wait on men, or run a bolt cutter for weeks—can do wonders in a few months. It will not make expert toolmakers, for only practice can do that. But it will give the toolroom foreman workers who can relieve his good men of much of the simpler routine work.

The First World War proved that effective training could be done rapidly. Such concerns as the Norton Company trained boys and young men in an astonishingly short time. So-called "vestibule schools," though designed primarily for teaching operators rather than toolmakers, proved that intensive training can accomplish more than we had realized. Where the hastily trained man or woman had not been so thoroughly trained as had been supposed, he or she was sent back to the school for special instruction.

Good teachers, imbued with the idea that it is just as necessary to teach a student *why* an operation is performed in a certain way as to show him *how*, can produce results that were impossible

under the old system. There must be a number of men still living who were very successful in these wartime schools. They should be given the opportunity to teach others the methods that were so successful during the stress of the last war.

TRAINING FOR SHOPMEN

Too many men in the tool industry have the idea that training refers only to the knowledge and skill learned during apprenticeship or other training period. Nor do they always recognize the many kinds of training that are necessary. There are few in industry, from top executives to office boys and apprentices, who know all that pertains to their job. Who is to say what training is necessary and how it can be given to the best advantage?

Correcting Faults.—There are training courses supposed to make all-round machinists in three or four years. There are also shorter training classes which make it possible for a man without previous experience to run a machine that is more or less automatic in its operation. Some shops find it advantageous to use these training classes to correct faults of individual operators, to boost their production by special training on operations in which they are a little below par, or to fit them to run more than one type of machine. It is usually found more economical to correct faults if possible than to train a new man for the job. It also boosts shop morale to avoid labor turnover as much as possible.

Emergencies.—How to train and what to teach are problems in any kind of training. In emergencies when it is necessary to utilize any kind of labor that is available, a routine teaching of the movements necessary to run a machine may be all that is necessary or advisable. But in ordinary times, when only applicants with some semblance of mechanical ability or inclination are considered, many find it better to include "why" as well as "how" in the instructions. This is especially advisable where men are trained to handle more than one type of machine, even if at some future time. Fewer mistakes will be made in shifting from one job to another if the operator understands why certain movements produce given results. This applies especially to feed, speed, and rapid-return motions on machines of various kinds.

In earlier generations the shop education of the apprentices was part of the job of the old-time foreman. The older mechanics also had a hand in teaching the apprentices in the ways of machining all kinds of work. Only in rare cases was there any planning or logical order of instruction. The work that happened to be in the shop was, of necessity, used to show how different machines and tools were used. Four years of this haphazard training usually made very good machinists. But it must be remembered that there were not more than half as many kinds of machine tools to be learned then as there are now. The various kinds of grinding machines, gear planers and hobbers, broaching machines, and jig borers and the many types of more or less automatic lathes were unknown. To learn all the present machines in use requires at least double the training in the same length of time.

Need for All-round Mechanics.—Machine-tool and other shops in which the mass-production methods of the automobile industry cannot be utilized require a larger percentage of all-round mechanics than any others, except the job or contract shop. Largely for this reason some of the most complete and thorough apprentice courses are found in the machine-tool shops. But even these shops have many parts made by repetitive operations that do not require men familiar with all the machines in the shop. These operations closely resemble many found in mass-production shops and only require machine operators instead of all-round men. It is obviously unnecessary to put operators for these parts through a four-year course.

One point to be carefully considered is the status of the boy who has spent four years in apprentice training. For though the apprentice today receives more money during his training period than the journeyman did fifty years ago, it is still much less than many skilled machine operators make either on piecework or by the hourly rate. A management that looks only at the immediate volume of production does not seem to appreciate the value of the all-round men they have trained. They talk of the value of skilled men but too often give them little substantial consideration.

In this connection it may be well to consider the difference between skilled and unskilled men. Although the terms are comparative and all machine operators acquire a certain amount of skill on their particular job, from management's point of

view there is a distinct difference. As the manager of one large shop said, "I pay unskilled labor for what it *does*, skilled labor for what it *knows how to do*."

Expanding this statement, he pointed out that the machine operator was paid for what he actually produced on the machine. The really skilled man was paid not only for what he actually produced but also for his ability to do whatever operation was needed. The value of the men who set up such intricate machines as screw-making automatics or spiral bevel-gear generators is far greater than the value of the operator of these machines. The set-up man may not be an actual producer of parts, but he makes it possible for a man with limited skill to get maximum production from these machines. In case of breakdown or derangement of any kind, the set-up man reduces the time lost to a minimum and makes it possible for the machine to earn dividends on its cost.

In a similar way, even though more indirectly, the maintenance man and the toolmaker may be paid for what they know rather than for the actual volume of work turned out. The maintenance man, the millwright of the old shop days, keeps the plant in running condition. He can often prevent delays as well as make them short when they occur. The expert toolmaker takes a sketch, or drawing, and produces a tool that does whatever job is necessary and earns its cost many times over.

Promotions.—The management that fails to recognize fully the value of the men who make it possible for others to produce is not likely to have a plant in which maximum economy is secured. Without these men the huge investment in machine equipment can easily become a liability instead of an asset. Some shops have a bonus system by which the maintenance men profit only when the machine, or department, is in operation. This encourages constant vigilance to prevent breakdowns.

While training is primarily for the young, there are many cases where it pays to consider the adult as well. This is particularly true where men or women are operators of one or, at most, a few types of machines. Here is where "life may well begin at forty" in many cases. Men who have worked as helpers or in clerical jobs with little or no future can often be trained to become good operators in a short time.

Giving an eager sweeper the opportunity to learn to run a hand turret lathe or a semi-automatic machine makes him a more useful member of the community. He increases his standard of living as his earning power advances; this is reflected in the business of the town and perhaps in that of his own shop, even though indirectly. It also adds to the morale of the shop by showing that management offers opportunities to its employees.

An observant sweeper often has quite a background of general knowledge of the shop and its products, which a new man lacks. Assuming reasonably good health, men of fifty or even sixty years of age can often be trained to advantage for many machine jobs. They are likely to be more careful and more dependable than very young men. And in spite of being beyond what we have considered as the "hiring age," they will probably average as many years of service as the younger men.

How to Train Shopmen.—Having decided on the kind, or kinds, of training, we are faced with the problem of how to give it. With few exceptions, schools separate from the shop are in favor as a starting place. Exceptions may be found in job shops where there is enough simple work to get the boy or man started. For schools to train all-round mechanics it is advisable to study the well-established institutions of the machine-tool and similar industries, such as those of the Brown & Sharpe Mfg. Co., the Cincinnati Milling Machine Co., and others. The Ford School in Detroit is also worth careful consideration and study. For while it may not be possible, or desirable, to follow either of these plans completely, many points will be found that will fit almost any situation.

Whether training is given in either the shop or a school, it is essential that the instructors *know how to teach.* It is not enough for the instructor to know how to do the work himself, he must be able to make the student know how to do it, and why it is done as it is.

Many plants have hard and fast rules as to the sequence of operations and the way they are to be performed. In some operations there seems to be but one way possible with the tools and equipment provided. But every shop has jobs that can be improved by changed methods. Frequently a new man knows of a better way, because of previous experience. And it some-

times happens that a new boy gets an idea that is worth trying.

Generally speaking there is no one best way for all men or for all jobs. Given a standard of quality and of labor cost, it often pays to let men do work in their own way, using of course the machines and tools provided by the shop. Management is concerned primarily in quality, cost, and contentment of the workers. Some prefer to have their work completely standardized by planners. Others resent such minute supervision and frequently work out methods that are more efficient than those previously used. Even where they are no better, the fact that they are permitted to try their own ideas gives a sense of satisfaction that adds to their loyalty to the concern which allows them to try out their own ideas. And loyalty of this kind is a real asset to any plant. Many improved practices have resulted from allowing men to try out their own ideas of production methods.

Here is also a point where foreman training plays an important part. Some foremen feel that the management should originate all new ideas. This makes them turn down new ideas from the men or claim them as their own. Both practices are against the best interests of the company.

Management should discourage any such attitude on the part of foremen, for it not only causes dissension in the shop but prevents many economies which might otherwise be put into practice. Encouraging the foremen to encourage their men to propose new ideas and new methods will pay dividends. The foreman's main job is as an executive, not as an inventor. He should not be supposed to possess all the brains and intelligence of the shop force. If he can get work out on schedule, at a fair cost, and keep his men happy, he is a success without inventing a single new idea or method.

The Bliss School.—A simple and effective type of apprentice school is in operation at the plant of the E. W. Bliss Co., of Brooklyn, N.Y., and is described briefly in extracts from an article in the *American Machinist*. The simplicity of the plan, the management's interest in the boys, and their keen interest in their work lead us to present it for consideration.

There is no formal indenture. The management feels that a dissatisfied apprentice should terminate his service at any time he desires.

Likewise the company wishes to be free to release an apprentice who cannot, or will not, measure up to the expected standard.

Apprentices must be between 18 and 21 and have high school education. Age, physique, education and family background also play a part in selecting candidates. Sons of employees are given preference, other facts being equal. The course begins with a few months in the school shop, which in some ways may be likened to the vestibule shops of war days.

The usual apprenticeship course is four years, in eight terms of six months. Those showing special aptitude for drafting can serve one or more years beyond the regular term and are graduated as draftsmen. Selection of this course is optional. All apprentices have extra instruction in drawing and in shop mathematics for $1\frac{1}{2}$ hr. two evenings a week. The school begins half an hour after the shop closes, giving time for a "snack" at the cafeteria.

After the usual preliminaries of joining the class, a new boy is introduced to each of the boys in the shop classroom. This practice contributes to the spirit of helpfulness that has replaced the old idea of "hazing" by sending a new boy after a "left-handed wrench" or "red signal oil." The first week is spent in watching the work being done. Then the boy is put on the first machine that is available for the simple jobs given to the beginner. All the work comes from regular shop products—there are no "practice" pieces.

An instructor stays with the new boy until he can handle the job given him, which may take two or three days. This instructor may be one of the advanced boys who is capable of instructing others. One of the advanced boys is made foreman of the school shop for three months, giving way to another boy at the end of his term. As the boy learns, he is transferred to other machines in the school shop, until in five or six months he is ready to go down in the shop on production work under a regular foreman. The quality of the training can be judged by the demand for boys from the school by the shop foreman.

In the office of the apprentice supervisor, whose personality has much to do with the success of this school, are wall charts that give a complete history of each student. These show by suitable markers the location of each of the 80-odd apprentice boys in the shop. In addition, the charts show each boy's progress from department to department and the quality of his work in each. This sytem checks the boy at all times and prevents his being held too long in one place. Another chart shows when an increase in pay is due. Notice of the advances goes to the accounting department a week ahead, so that there will be no delay. When the increase is made, it is checked on the chart and the date of the next raise, six months hence, is marked.

Classes are held two evenings a week in shop mathematics and in drawing. These are under the supervision of the chief engineer and his assistants, who have worked out many problems having practical application to the work done in the shop. Drawing is taught to enable correct reading of blueprints by the boys rather than to make them draftsmen. Models and blueprints in isometric perspective are used in this work. Perspective prevents direct copying of a projection blueprint and makes the boy familiar with the difference in appearance between the object as shown in perspective and the usual projection drawings.

The Honor Council

Perhaps the outstanding feature of the Bliss apprentice system is the Honor Council, consisting of seven boys elected by the whole school. This council settles differences of opinion and grievances regarding personnel matters. It determines necessary discipline, metes out punishment when necessary, and has recommended discharge in one case. No foreman may discharge an apprentice, though he can request his transfer to another department. Such requests are unusual, and there are more cases where the foreman asks that the boy remain in his department longer than scheduled.

School hours, especially when they come at the end of a workday, are seldom very popular. This school is an exception, for which there seems to be only one reason—personality of the instructors. They, through an enthusiastic interest in the boys, have developed lessons and explanations of principles that are of genuine interest. Thus, instead of watching the slowly moving clock hand, the apprentices are likely to delay departure as long as possible. This was true of a recent examination. The boys asked for more time to solve their problems. Some of them stuck long after usual hours, determined to solve the questions no matter how long it took. The result was an astonishingly high average mark for the whole class. Another feature, which is a sensible innovation, is permission to use note books in solving examination problems. Few engineers attempt to remember all the formulas they use; they consult handbooks. The main thing is to know how to apply formulas. That is what these boys do at examinations.

Back of the success of this apprenticeship system is the personnel of the entire management. The apprentice supervisor has great enthusiasm for his boys and for the cooperation of his superiors. The factory manager is genuinely interested in its success and in every apprentice in the shop. The entire personnel understands boys and how to gain their confidence and respect. These men realize that varying temperaments require different treatment for best results. The individual is

considered as such and treated in a way calculated to bring out the best that is in him.

Last, but an important item, is the rate of compensation. In 1937 it began at 35 cents per hour with a raise of four cents an hour every six months if progress was normal. This brought wages in the final six months up to 63 cents per hour, which is a revelation to those who remember apprentice's and journeyman's wages of the last century. The changes in apprenticeship ideals and methods have been as great as that of the wage scale. With such apprenticeship methods in general use we should soon have an ample supply of good mechanics.

TRAINING TOOLMAKERS

Numerous plans for training young men to become toolmakers have been put forth. The best plan to be followed in any shop depends to a large extent on the human material available and on the size and equipment of the plant.

Selection.—If boys or young men who have had no experience with tools are to be trained, there is much elementary work to be done before toolmaking is to be seriously considered. On this account some shops prefer to pick their apprentices from bright young men in the production department. These men already have many of the fundamentals of machine operation and machine work and make excellent material for future toolmakers. They can be trained in much less time than boys or men with no practical background.

One of the primary requisites for a toolmaker is the physical co-ordination that we call skill or deftness. The naturally clumsy man must overcome this handicap in order to get far in the toolroom. Sensitiveness of touch in women has been found a great asset in toolrooms during emergencies, as well as on inspection work. But deftness alone is not enough except in toolrooms where the work can be subdivided. A mechanical background, or machine sense, is a great asset where any original work is to be done. Where a shop can pick its toolmaker apprentices from the production department, both deftness and machine sense can be easily discovered among the possible students.

Example of Training Course.—The National Cash Register Company has a four-year course for toolmakers that has much to commend it. Details of the schedule for each month are given in the lists that follow. They will be well worth careful study by those interested.

Where They Start.—Generally speaking, the first four months are given over to having the apprentice become familiar with the different kinds of tools and parts. The time is divided between jig and fixture work and the use of punches and dies. Two months on the hand screw machine follow, after which come four months on the engine lathe. Two months on the shaper complete the first year.

Toolmaking Apprentice

First Year

During the first year the apprentice is required to attend the owl class in blueprint reading.

1st month	Helper, supply room—crib 2.—Handing out hand tools and stock parts peculiar to jig, fixture and gage work.
2d month	Helper, supply room—crib 2.—Handing out hand tools and stock parts peculiar to jig, fixture and gage work.
3d month	Helper, supply room—crib 1.—Handing out hand tools and stock parts peculiar to punch and die work and small tools.
4th month	Helper, supply room—crib 1.—Handing out hand tools and stock parts peculiar to punch and die work and small tools.
5th month	Hand screw machine—centering machine and cut-off saw; machine section.—Taught cut off, centering, drilling, reaming, tapping, and chamfering. Use of drills, reamers, scales, plugs, etc. Application of speeds and feeds.
6th month	Hand screw machine—centering machine and cut-off saw; machine section.—Taught cut off, centering, drilling, reaming, tapping, and chamfering. Use of drills, reamers, scales, plugs, etc.
7th month	Lathe.—Taught rough-turning counterbores, reamers, arbors, and cutters. Use of calipers and micrometers. Application of speeds and feeds.
8th month	Lathe.—Taught finish-turning, taper-turning, and external threading. Use of taper receivers, thread wires, micrometers, and receivers.
9th month	Lathe.—Taught faceplate setups, boring, and turning. Use of angle irons, bolts and clamps, and balance weights.
10th month	Lathe.—Taught working to detail drawings in producing parts for general tool construction.
11th month	Shaper —Taught plain flat and edge work on tool and stock details. Use of square, grinding of tools, etc. Application of speed and feeds.
12th month	Shaper.—Taught step work, angles, radii, and form shaping Use of bevel protractor, depth micrometers, and radius gages.

Ten months of the second year are devoted to milling, bench-lathe work, grinding, and lapping. During the last two months of this year the apprentices begin actual work on tools, thirteen months being given to punch and die work. It will be noted that several months of the third year are spent in the shop under direct supervision of journeymen instructors. Apprentices remain on the payroll of the toolmaking department.

Fourth-year Schedule.—Jig, fixture, and gage work follow, the same sort of shopwork being done as on punches and dies, as

TOOLMAKING APPRENTICE

Second Year

The second year the apprentice is required to attend the owl class in mechanical drawing

1st month	Milling machine—hand.—Taught cut off, slotting, use of saws, lubricants, speeds, and feeds.
2d month	Milling machine—power.—Taught plain milling, use of straight and spiral fluted cutters, and application of speeds and feeds.
3d month	Milling machine—universal.—Taught dividing head plain and spiral, also universal vise.
4th month	Milling machine—automatic.—Taught setup and operations of hobbing machines and gear cutters. Application of speeds and feeds.
5th month	Bench lathe.—Taught setup and grinding of small diameters, external and facing. Application of proper grinding wheel and practice.
6th month	Grinder—external.—Taught plain cylindrical grinding and use of amplifier gages.
7th month	Lapping—external.—Taught use and application of abrasives to precision lapping of plug gages and studs, etc.
8th month	Lapping—internal.—Taught use and application of abrasives to precision lapping of receiver gages, bushings, etc.
9th month	Grinder—surface.—Taught plain surface grinding to tool and die details. Use of proper grinding wheel.
10th month	Grinder—surface.—Taught setup of angle and step-grinding of tool and die details.
11th month	Die-shoe assembly and get ready.—Taught assembly of die shoes lineup, fit, and checking, also layout from detail drawing of die parts. Drilling, reaming, co-boring, and tapping.
12th month	Punch and die work.

outlined in the schedule. The details listed show that great care has been given to the various operations that enter into the making of tools.

It will also be noted that all apprentices attend evening classes on such subjects as reading of blueprints, mechanical drawing,

TOOLMAKING APPRENTICE

Third Year

The third year the apprentice is required to attend the owl class in shop mathematics

1st month	Punch and die work
2d month	Punch and die work
3d month	Punch and die work
4th month	Punch and die work
5th month	Punch and die work
6th month	Punch and die work
7th month	Punch and die work
8th month	Punch and die work
9th month	Punch and die work
10th month	Punch and die work
11th month	Punch and die work
12th month	Jig-body assembly.—Taught milling, drilling, reaming, fitting, and assembly of standard jig bodies.

Time: 12 months

Taught repair, change, and making of new
- Blanking dies
- Forming dies
- Shaving dies
- Piercing dies
- Compound dies
- Combination piercing and shaving dies

This work will be done under the direct supervision of a journeyman instructor to whom the apprentice has been assigned as a helper until such time as his understanding of the processes involved will permit him to shift for himself.

During this period the apprentice will be assigned to other departments at different intervals, total time not to exceed one month, to witness, experience and use the tools upon which he has worked.

Apprentices will remain on the toolmaking department pay roll during these intervals.

and shop mathematics. This entire course has been carefully thought out and should be of great service to those who have not had similar experience.

Toolmaking Apprentice

Fourth Year

The fourth year the apprentice is required to attend the owl class in advanced shop mathematics

1st month	Jig, fixture, and gage work
2d month	Jig, fixture and gage work
3d month	Jig, fixture, and gage work
4th month	Jig, fixture and gage work
5th month	Jig, fixture and gage work
6th month	Jig, fixture and gage work
7th month	Jig, fixture and gage work
8th month	Jig, fixture, and gage work
9th month	Jig, fixture, and gage work
10th month	Jig, fixture, and gage work
11th month	Jig, fixture, and gage work
12th month	Jig, fixture, and gage work

Time: 12 months

Taught repair, change, and making of new

Jigs:
- Locating
- Feather pinning
- Drill

Fixtures:
- Profile
- Mill
- Tapping
- Filing
- Straightening
- Bending
- Engraving

Gages:
- Milling
- Drilling
- Tapping
- Profiling
- Engraving
- Forming
- Receiver

This work will be done under the direct supervision of a journeyman instructor to whom the apprentice has been assigned as a helper until such time as his understanding of the processes involved will permit him to shift for himself.

During this period the apprentice will be assigned to other departments at different intervals, total time not to exceed one month, to witness, experience, and use the tools upon which he has worked.

Apprentice will remain on the toolmaking department payroll during these intervals.

KEARNEY & TRECKER CO. APPRENTICE PLAN

All agree that more apprentice training is necessary, but too few have definite plans and facilities for carrying out the idea. According to Mr. Havlista, employment manager and apprentice supervisor for the Kearney & Trecker Co., they try to choose their apprentices carefully, and they train them right in the shop. He points out, "Unless we pick the right boys, we are wasting their time and ours. This is not fair to either the boys, ourselves, or the community, as a misfit hurts all three. When the boys work in the shop, they learn to get along with tough foremen as well as the easy-going kind." The company takes only high school graduates from eighteen to twenty-two years old, and they must attend night school during the apprenticeship of four years. There is a probationary period of 3 months before the boy is finally accepted. Their ability to pick the right boys is shown by having only 16 out of 139 cancel out their contracts in four years.

Time Plan.—The term covers 8320 hr., based on 40 hr. per week and 52 weeks per year. One day each week is spent at the Milwaukee vocational school, making a minimum total of 576 hr., which counts toward the 8320 hr. total. The instruction includes: drilling machine, 175 to 525 hr.; milling machine, 1040 to 2080 hr.; screw machine, engine lathe, turret lathe, and boring mill, 2080 to 3120 hr.; planer and grinder, 1040 to 2080 hr.; assembling and erecting, 1040 to 2080 hr. Rates start at 30 cents per hour and reach 55 cents during the last period.

Shifted at 4-week Intervals.—Two or three days are required on tool grinding. Tool bits for practice grinding are of $4 \times \frac{3}{8}$ in. square cold-rolled steel. After the apprentice has mastered the grinding operation, he is given tool-steel bits to grind. He then goes to work on a small lathe where he does straight turning and facing operations. After 4 weeks he is transferred to another lathe where close tolerances are held and micrometers are used. Four weeks later he is assigned to a larger lathe where more difficult operations are performed. The next 4 weeks are devoted to larger work and also taper and thread cutting, boring, and tapping.

The fifth 4-week period is intended to give the apprentice all-round training. His duties are to fill the place of one of the four

other apprentices in his department, each being assigned a different school day. Since only four lathes are assigned to the group, no lost machine time is encountered by this arrangement. All other departments and changes are scheduled in the same manner, thereby giving apprentices regular changes at set intervals. During the sixth period of 4 weeks, he acts as a utility man and is responsible for the quality of work and production of the other five apprentices in the lathe department. In case a regular employee is absent, he fills that vacancy. As a utility apprentice, he has an opportunity to show his junior executive ability.

The Utility Squad.—The company has also established an apprentice "utility squad." Four apprentices are selected who are always available to help in emergencies and to fill vacancies in any department caused by absence of regular employees. In case there is an idle machine or an important job and emergency help is needed, a foreman can request the services of one of the members of the squad. The foreman in charge of such an apprentice immediately releases him to the other department.

The maximum time of emergency-squad service in any one department is limited to 1 week for each apprentice. Such an apprentice must be replaced by another, in the event the department does require additional help. This limitation is established so that all utility-squad apprentices may benefit by this special training.

Regular Promotion Assured.—Apprentices are promoted from one class of work to another according to a regular schedule planned in advance, the time in each class of work varying with the duties which have to be performed. Each apprentice is under direct charge of the foreman for whom he works. The apprentice supervisor deals directly with the foreman when incorrect training methods are used. This plan eliminates friction and sells the foremen on apprenticeship, which is one of the most important factors of a successful program.

Weekly Classes.—Apprentice meetings of 1 hr. are held weekly to discuss such subjects as time studies, cycle work, management of departments, sales and advertising, mathematics, trigonometry, slide rule, and shop theory. Shop trips are made through the various departments with the foremen in charge acting as guides. Lectures are given by members of the sales

and cost departments, by patternmaking foremen, road salesmen, and others. Technical literature is furnished.

Machine-shop arithmetic problems are extra homework for the boys. This is noncompulsory, but it has been found that nearly all the boys are ambitious enough to do this extra work. Night-school attendance, which ranges from one to four nights a week, is also required of all apprentices, without pay. However, credit is given on the indenture time for the hours of night school attended. Weekly reports and sketches of work and the jobs handled are required of each apprentice.

At the completion of the indentured time, the apprentice goes to the foremen in the various departments in which he has worked and asks for a regular job. When he is accepted by a foreman, it is almost certain that he did a good job in that department and is placed in the plant for the best use of his service.

Between 60 and 100 apprentices are recommended for a shop of 1200 men. They are assigned as in the accompanying table.

TABLE 14.—RECOMMENDED MINIMUM MACHINE-SHOP APPRENTICES FOR SHOP EMPLOYING 1200 MEN

Department	Number of Machines	Number of Apprentices	Department	Number of machines	Number of apprentices
Lathe	4	6	Assembling gear run in	1	1
Turret lathe	4	6	Tool inspection, layout floor	..	5
Planer	4	6	Inspection	.	2
Gear cutter	2	2	Experimental room, lathe	1	1
Milling machine	4	6	Experimental room, milling machine	1	1
Drill press	2	4	Dividing-head bench	..	1
External and surface grinder	3	4	Lo swing	1	1
Inspection and bench	.	4	Saws	4	5
Cutter grinding, thread miller, internal grinder	4	5			
Erecting	..	5	Total	35	65

CHAPTER 9

MANAGEMENT

Management, in its broader sense, is the foundation of all business, whether it is a one-man shop or a huge, mass-production plant. It includes locating and equipping the shop, securing work to keep it busy, finding men and women to run the machinery and the office, producing work that will be satisfactory to the customers, setting prices that will be profitable, and collecting pay for the work done. There are also such details as insurance of all kinds, purchasing materials at the right prices, and probably organizing a sales department.

RELATIONS WITH THE MEN

Although it is not easy to say which of these is more important, the selection and handling of both men and machines stand high in the list, and personnel can safely be considered the biggest problem. Co-operation and loyalty are the two main factors in the personnel of any shop, but they must work both ways to be successful. Most men will be loyal to a boss who has always played fair with them. If he stretches work to tide them over a dull season, they can be depended on to help pull him out of a hole when he is in a jam.

The smaller the shop the greater the opportunity for both men and management to know each other's problems. The boss knows when one of his men has sickness at home that keeps him up nights and distracts his mind from his work. The men know when the boss is being pushed for delivery of work or for payments on new equipment or materials. When both sides understand and play fair, there is little chance for misunderstandings.

As the shop grows, there is less opportunity for personal contacts. The boss must delegate authority and personnel relations to others. The men in large shops must delegate authority to represent them. The right kind of assistants and delegates can maintain the same friendly feelings as before, but

unless the right kind are selected, the management is letting itself in for a lot of trouble.

HARMONY AMONG SHOP EXECUTIVES

With few exceptions, all businessmen agree that harmony, or "getting on with each other," helps any shop to prosper. It certainly makes life more worth while for all concerned.

Harmony does not mean that one man or one department should try to hide the mistakes of the other. But when mistakes are made, all should work together to rectify them in the best way possible. For while individual initiative is desirable, the output of any shop depends on teamwork among the men and the different departments.

Friendly rivalry between individuals or departments is an excellent tonic in every way. But when rivalry reaches the point of trying to put the other man or the other department in the hole, production suffers and shop morale gets a decided setback. Teamwork, or co-operation, is more necessary than ever before.

A few big executives of the old school still cling to the idea that antagonism between department heads produces the best results. They argue that with each foreman and superintendent on the warpath for all the others, all mistakes are brought to light and each foreman strives to prevent the other from getting anything on him. Foremen's or superintendents' meetings in such plants are marked by antagonisms and epithets that belong to the darker ages of industry. Fortunately, such conditions and rivalries have given way to teamwork in most plants.

Foremen's Meetings.—Some shops hold a short foremen's meeting in the superintendent's office each morning, or at less frequent intervals. Each foreman gives a brief outline of the condition of the work in his department. If he is in danger of running out of material, the purchasing department hears of it and gets busy. If work has been delayed in one department for any cause such as illness of an operator or the breakdown of a machine, plans are made to keep the work going through so as to avoid delay in the operations that are to follow.

Each foreman knows what is expected of his department and reports on the prospect of fulfilling his schedule. In this way the superintendent gets a picture of the work in the whole shop

and takes steps to correct delays in any department that may affect the output of the finished product. And we must not forget that it is only the finished product that brings money into the cashier's office.

Meetings of this kind must be rather carefully planned, however, and kept alive by a little judicious steering by the superintendent or even the big boss. Otherwise they are likely to become a sort of social club where men tell of the fish they didn't catch, the gas mileage of their new cars, or the latest score at golf.

Some find it best to have the foremen report in reverse order, that is, the assembly foreman tells what shipments his schedule calls for that day. Other foremen can then tell him whether the parts he needs are ready or when they will be ready.

In this way the reports work back to the foundry, the smith shop, and the purchasing agent, if there is one. If each can report that the parts or the materials needed by the next man are ready, the superintendent knows there is no reason why work schedules cannot be kept. If materials or parts are not ready, he knows exactly where the bottlenecks are and can apply remedies without delay. Meetings of this kind can be made very useful even in comparatively small plants. They need only take a few minutes in many cases, since the superintendent can prevent delays and waste of time. With each foreman knowing just when he can expect his work from other departments and when the next department must have the work he is doing, all work will move faster and more smoothly than where meetings of this kind are not held.

GOOD WILL

Good will, stated by some philosophers as "an advantage created by turning out good work" is more than that—much more. It is created in a large measure by turning out not only good work but good work on time and at reasonable cost to purchasers. It involves also such attitudes toward employees and associates as will gain from them the highest degree of respect and willingness to cooperate to the fullest extent. Good will gets and holds business and holds good men in the skilled ranks of the shop.

Good will is one of the important assets that a man can acquire in part before he actually launches a business of his own. His contacts with shop problems and associates should help him to build a future group of prospective customers who may want to bring definite jobs to his plant after he gets the new business under way.

For plants long in business, good will is of inestimable advantage. It may equal in importance the physical assets of the whole plant, for plant equipment can be purchased, good will cannot. It is developed by faithfulness in business contacts and by responsibility to one's markets in the very broadest sense of the word. Reputations established must be maintained, or good will diminishes rapidly. The good will built up after years of effort must be guarded carefully by succeeding managers operating under newer conditions but with similar ideals of business performance.

Good will is the outgrowth of methods that give satisfaction to customers. It results in successive orders from firms assured through past experience of good work from the producer. It is held in high regard by manufacturer and consumer, and it has often led to the placing of important orders upon the display of a mere blueprint without doubt upon the part of the customer of any difficulty arising in the satisfactory carrying out of requirements when the machine is actually built. Such faith in the designs and constructions of a plant are only acquired upon a long record of faithful performance in the past.

WHAT THE "BOSS" DOES

Many people have the idea that the "big boss" really has an easy time. They, and the boss too, may be interested in the following description of the boss's problems from *Advertising Age:*

An Executive Has Nothing to Do

As everybody knows . . . an executive has practically nothing to do . . . That is . . . except . . . to decide what is to be done . . . to tell somebody to do it . . . to listen to reasons why it should not be done . . . why it should be done by somebody else . . . or why it should be done in a different way . . . to prepare arguments in rebuttal that shall be convincing and conclusive. . . .

To follow up to see if the thing has been done . . . to discover that it has not been done . . . to inquire why it has not been done . . . to listen to excuses from the person who should have done it . . . and did not do it . . . to follow up a second time to see if the thing has been done . . . to discover . . .

That it has been done but done incorrectly . . . to point out how it should have been done . . . to conclude that as long as it has been done . . . it may as well be left as it is . . . to wonder if it is not time to get rid of a person who cannot do a thing correctly . . . to reflect that the person in fault has a wife and seven children . . . and that certainly . . .

No other executive in the world would put up with him for another moment . . . and that . . . in all probability . . . any successor would be just as bad . . . and probably worse . . . to consider how much simpler and better the thing would have been done had he done it himself in the first place . . . to reflect sadly that if he had done it himself . . . he would have been able to do it right . . .

In twenty minutes . . . but that as things turned out . . . he himself spent two days trying to find out why it was that it had taken somebody else three weeks to do it wrong . . . and then realized that such an idea would strike at the very foundation of the belief of all employees that . . .

An Executive Has Nothing to Do

OVERHEAD

Overhead is an all-embracing term that is sometimes used to include all expenses except labor and material. Failure to understand all that may be implied by overhead has caused many business diasters.

Lumping all sundry expenses under one heading may make easy bookkeeping, but makes it very hard to trace leaks or to prevent waste. Overhead includes such items as rent, taxes, fire and other insurance, wear and tear on machinery or on buildings, interest on money invested in buildings, machinery, and stock, and supervision. The longer it takes to turn the raw material into the finished product and to get paid for it, the greater the overhead.

Overhead also includes the cost of selling (which means advertising, circulars, catalogs, and sales commissions), travel expenses, and the like. Supervision includes the salary of the owner as well as those of superintendents, foremen, and other employees.

Many small-shop owners fail to consider their own wages or salary as part of the cost of doing work. This failure leads them to give estimates that are too low and they lose money. Here is one of the main reasons why so many small shops go out of business after a few months or years. It is also unfair to those shops which, understanding all the costs that should be included, bid high enough to cover them all.

Many customers fail to realize that they are frequently hurting themselves by accepting bids which they know are so low that the bidder cannot make a fair profit. By accepting such bids they may force a very reliable source of supply out of business. Unless we permit the other fellow to make a profit, we cannot continue our present system of doing business.

Owner's Investment.—One kind of overhead that some fail to understand is that relating to their own investment. Even if they own their shop, they must charge themselves rent. This should be enough to cover all the money invested at the current rate, or that it would earn if invested safely elsewhere. In the same way the use of the machines must be charged for at a fair rate, although this is not easy to determine in all cases.

Rates.—It is quite common practice to charge a fixed rate per hour for all work done, whether it involves the use of a $10,000 machine tool or only a bench and vise. This means the man whose work uses the machine pays too little and the other customer too much, unless the shop loses money. While this might average out with a wide variety of work, it is still unfair to the customer with the handwork. If the use of expensive machine equipment predominates, the charges will not cover interest on the investment, maintenance, and depreciation.

One good way is to set an hourly rate for the use of each machine based on its cost and on the maintenance and depreciation money which should be set aside for its replacement when it wears out or becomes obsolete. This may seem like a lot of paper work, especially in a small shop, but it must be done if one is to stay in business and make a fair profit.

Where the machine equipment is old and only jobbing work is done, a flat hourly rate can usually be established that will probably answer all requirements. But it is all too easy to fool yourself as to the total costs of a job. When this is done too

frequently, the shop goes out of business without waiting for the sheriff's sign on the door.

Breaking Down Overhead

By dividing overhead expense into several general headings it can be considered with less difficulty. The subdivisions might be:

Rent and insurance of all kinds.

Cost of getting business, whether by mail, advertising, or personal solicitation. This will include many traveling expenses as well as time.

Cost of supervision and training. Even small shops should consider some form of training, not regular apprentices, perhaps, but with a view of improving the quality of work and getting machine operators. Judicious training of some who are fair mechanics will frequently help both employer and employee.

Cost of spoiled work. There are many methods of reducing the amount of spoiled work, some of which will be discussed. Any saving here is a direct gain to all.

New machines and maintenance.

Shop supplies, such as drills, taps, and reamers, which require frequent replacement.

By keeping these accounts separate it is much easier to detect waste and unnecessary expense.

Costs of Machines.—Costs of many of the items listed above can be kept down by securing the cooperation of the men. Some shops find it advisable to have the men know and appreciate the cost of the machine tools they run. The Monarch Machine Tool Co. supplies a metal plate on its lathes which shows the date of purchase and the cost in addition to the size and serial number. This is not only a plain statement of the value of the machine and a constant reminder that care is necessary, but a visible record to the management of its age and cost.

Many shops keep a record of the cost of maintenance of each machine. This not only contributes to the shop records but is a valuable guide when new machines are to be purchased. These records show not only the cost of repairs but the time the machine was out of commission. Idle time, when a machine is not producing its quota of work, may be even more important than the cost of the repairs themselves, for the failure of a single machine may tie up production in a whole department.

Percentage of Overhead

Considering the percentage of overhead on the basis of direct labor cost was formerly the universal custom and still prevails in too many cases. This method has many drawbacks, especially where an attempt is made to limit the overhead to a fixed percentage. When this is done, the results are likely to be very misleading and have sometimes led to decisions that were very uneconomical.

The prime object of all machinery is to save manual labor. In many cases it also gives greater accuracy to the product and saves money by reducing the time taken in assembling the parts into a complete machine. But it should be thoroughly understood that the more labor that is saved by the machine, the higher the machine overhead must be when based on the cost of direct labor. An increase in the cost of supervision also boosts the percentage of overhead when based on direct labor cost. This shows why a low overhead cost, based on direct labor, may prove inefficiency rather than the reverse, as many seem to think.

Overhead Related to Direct-labor Cost.—Many oldtime shop managers set the limit of economical overhead at 150 per cent or $1\frac{1}{2}$ times the cost of direct labor. This arbitrary ratio has prevented the installation of new machines that would have saved money and has discouraged better management. This is shown by the experience of one industrial engineer who had installed new devices, designed new tools, and otherwise cheapened the cost of product in one large establishment where the general manager had the fixed overhead in his mind. In spite of the fact that the engineer had reduced costs and that the product was being made for less money than ever before, the engineer was discharged to bring the overhead down to the deadline of 150 per cent. Modern managers know that with highly mechanized departments, where machines are very efficient, the overhead frequently runs to 350 per cent of direct labor, and sometimes even more.

A job shop will have a much lower overhead percentage than a well-equipped manufacturing plant. But the job-shop owner should remember that as methods become more efficient, the cost of direct labor becomes a smaller part of the total cost.

This is equally true whether the improvement is due to machine equipment or to better methods.

Time for Contacts.—It frequently happens that in endeavoring to avoid hiring a clerk or bookkeeper, the owner of a small shop tries to do too much himself. Frequently his wife tries to run the office as well as her house. This is most natural when a business is small and money is scarce. In such cases, however, the work done by both the man and his wife should be counted in making up estimates and in determining prices and profits. Many good-sized businesses started in this way.

In many cases, however, it would be cheaper in the long run for the proprietor to hire an assistant so that he can devote his time to work that is more important. Usually this time will be more valuable if devoted to making acquaintances among possible customers or to soliciting business. Letting people know the kind of work you can do and your facilities for handling special kinds of work often brings business from unexpected quarters.

There may be times when it will pay to have the owner handle intricate jobs in the shop. Ability to do this frequently helps build the morale of a shop and increases loyalty to the "old man." Supervision that prevents or minimizes spoiled work is much more important than saving a little clerk hire. This is especially true when speedy delivery of work is involved, in addition to preventing losses of time and materials.

Overhead is, however, something to be watched with great care. It should be separated into a number of distinct divisions instead of being lumped into a "catchall" for all items that are not direct labor or materials and may be a bit difficult to place. In some shops "general expense" covers many costs that might be eliminated with care and study, and study is easier when costs are itemized and segregated.

WHAT IS WORKING CAPITAL?

Just what working capital means to a business is explained by the General Motors Co. to its employees in its magazine *Folks*, as follows. The illustration, Fig. 124, helps make it clear.

Net working capital is the total amount of funds available for the day-to-day, or current, needs of the business.

Working capital dollars are called on to do several different kinds of jobs. When orders come in (or there seems to be a fair prospect for

orders in the near future) raw materials and supplies must be purchased and stored ready for use. You know how important it is always to have on hand the right amount of each of the many raw materials we need, so that there are no interruptions in production.

As the work progresses there is a lot of material moving through the shop "in process" and finally there are finished parts, component parts, or finished products which are stored until sold. All of these—raw materials, work in process, and finished products—go to make up *inventories*. Maintaining inventories is one of the important uses of working capital.

A considerable part of working capital usually is in cash or cashable securities, needed to meet the expenses of the business as they arise.

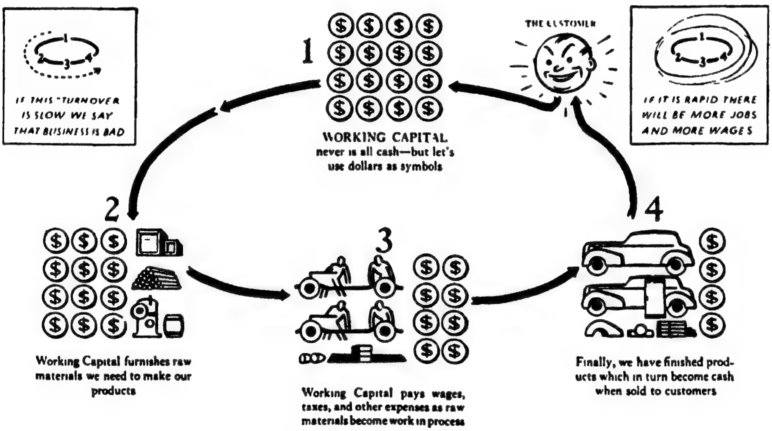


FIG. 124.—The flow of capital.

Thus, provision must be made for meeting payrolls, bills for materials, freight, advertising, working tools, and other regular expenses. Most businesses try to keep at least enough cash on hand to meet bills for sixty days.

At certain times of the year a major part of our working capital is tied up in *inventories*, leaving our cash relatively low. At other times cash must be built up so that payrolls and bills can be met when things begin to pick up. During the winter months a part of our cash is used to build up inventories and this evens out employment.

Taxes are another expense which must be met promptly. Dividends to stockholders for the use of their savings also are paid from cash on hand.

In many ways, working capital is to a business what gas in the tank is to a car. No matter how fine and mechanically perfect a car may be,

without gas in the tank it is of no use to anybody. A business suffering from lack of working capital can't run very long or very well.

For that reason, it is one of the first responsibilities of management to see that adequate working capital is on hand to meet payrolls, buy raw materials, provide for power and light, maintenance of tools and plants and all the other expenses so that work can go on without interruption.

Of course, the *customer* is the driver of the car of business. When he steps on the accelerator it means that the flow of working capital through the business is speeded up and things begin to hum. By doing our best to give the customer the greatest possible value for his dollar all of us can help encourage him to "step on it."

But the working capital dollars must be there and ready to use when the customer decides to step on the gas, because on working capital depends the day-to-day operation of the business—the purchase of raw materials, the payment of wages, and all the other activities that keep a business going.

EXPANSION

Sooner or later every successful business reaches the point where the shop cannot turn out as much work as customers demand. Customers and friends urge expansion of the shop and business—build, buy, or rent more space and acquire machine equipment to handle more work. A rush of business is a warning sign to stop and consider before doing anything rash.

Extra Shifts.—The cheapest way to increase capacity is usually to put on an extra shift or work one shift overtime. This reduces machine and plant overhead by getting more work out of the same plant. But it is never all clear gain. In most cases overtime and night-shift workers demand and get extra pay per hour or week. Work at night, on Sundays, or on holidays often pays from 1½ to 2 times the regular rate. This is considered the usual practice in most places. The original reason was to prevent working the same men more than the standard number of hours, to *discourage* overtime, and to encourage the employment of more men in two or three shifts. Plant expansion should be the last resort as a rule.

But even without extra pay, overtime and two or three shifts invite new problems. Supervision and tool or machine breakdown are liable to be larger items than were anticipated. On continuous runs of the same product with semi-automatics or turret lathes, there need be little trouble from the operating

point of view. But the foreman problem is more difficult. It is not easy to have work flow smoothly from one shift to the other. Unless the foremen "lap over," there is likely to be confusion in changing over from one crew to the next.

The plan of having the foreman come on duty from ½ to 1 hr. before the shift changes often works out well. In this way the incoming foreman can receive full information as to how the work is progressing. If a certain operation or machine needs watching, or if a delay in delivery of materials seems possible, he may be able to minimize the delay if he knows about it in advance. Many shops find it advantageous to have the foremen on salary instead of hourly rates.

It is particularly important to realize the value of good supervision under such circumstances, and it pays to be generous with foremen who keep the shop running smoothly under such conditions. There have been too many cases where foremen have had to see some of their semiskilled men receive a larger pay check than their own in piece work and in rush times. Foremen as a rule are loyal and often long-suffering. But unless the employer is loyal to the foreman as well, the shop suffers.

Need for Expansion.—Deciding whether to expand or not is a very serious question. Expansion means more capital invested in buildings and tools and a greatly increased overhead in slack times. It is usually better to turn down business than to become too deeply involved in trying to prevent its going to some other shop.

Among the questions to consider are: Why the increase in demand at this time? Is it because people fear a rise in price and wish to place orders at the old rate? Is it from some very unusual cause, such as war, blockade, or embargo in some other country? Or is it due to better business conditions or to the merit of our work or designs?

If the reason is fear of rising prices, it is unwise to be stampeded into taking too many orders, even if they can be filled by working overtime. Such orders frequently mean a hectic rush for two or three weeks or months and then a drop to below normal. It is better to run the shop at a normal rate for six months than to run two shifts for three months and half time, or less, for the other three. There is less worry for the owner, less trouble in the shop, and more net profit.

Should it become necessary to enlarge the shop to meet government emergency, it is better to build a temporary extension and tear it down when the slump comes. Many shops that expanded greatly in the 1916–1919 period had a white elephant on their hands for many years after.

Another way to avoid expansion is to have some of your parts made in another shop, or shops. This is far preferable to having an entire machine sublet to another shop. Where parts are made by others and assembled in your own shop, you can control the quality of the work that bears your name, for each complete machine will be checked by your own men before it goes to a customer. Otherwise, it will be necessary for you to keep an inspector in the other shop, and even then it is not so satisfactory as assembling the machine yourself.

Another advantage of only having parts, or even subassemblies, made outside is the effect when business slacks off. If you sublet the whole machine, you may have a potential rival when you no longer need his work. But if he only makes parts, he is far less tempted to enter the field with a complete machine.

Natural Growth of a Successful Business.—Unfortunately, at least in the minds of some, a successful business can seldom remain in the small-shop class. Many successful men have tried to prevent their businesses from expanding beyond the point where they could no longer keep a finger on all details. The businesses grew in spite of them. And men who had run a small shop successfully and happily, found themselves forced to expand and to delegate authority to others.

Then, too, there are men who succeed in a small shop where mechanical genius is necessary to solve the many small problems that come along, but who fail when the shop grows larger. They are small-shop men and can never be anything else. Many small-shop foremen who can tackle any kind of job fail in shops where they must get production from the average type of mechanic available.

When a shop gets to the stage where the owner must delegate authority, management must change from memory to records of some sort. Orders, facts which affect the business, must be put on paper for others to see and act upon. More "paper work," which small shops can largely ignore, becomes necessary. Authority must be delegated and parts given to others. This

is not easy for one who has had every detail in his own head and hands. And in many cases, the larger the business and the wider the distribution of authority, the less efficient is the management. It is for this reason that small concerns can frequently underbid organizations with widespread plants and large executive staffs. For while the actual production efficiency may be higher in the large plants owing to special machine equipment, the lost motion in handling orders, in getting materials, and the resulting confusion add much to the cost of the product. The automobile industry is an example of this, as well as the large steel companies. Small, independent concerns can sell various products as cheaply as the huge combinations and in some cases make at least as good a profit.

If, after careful study of the market and of business conditions in general, expansion seems advisable, it should be done as carefully and as wisely as possible. It must be remembered that overhead goes on relentlessly even though the addition to the shop may stand idle. Every effort should be made to keep this overhead as low as possible consistent with good management.

It frequently happens that machines can be so arranged that one man can perform operations on several machines in slack times, even though he only handled one when business was good. This means a flexibility of arrangement that takes careful study when laying out a new plant, or in extending an old one.

While labor costs rarely drop in proportion to the falling off in volume of work done, overhead increases per unit of work. An attempt to add this to the price of the product may be disastrous, and should be avoided. Management has to figure out a way of keeping the shop going until there is sufficient business to bring costs and profits back to normal.

Too Much System.—While many shops need more system, some have so much that it prevents efficient operation. One particularly bad system is to put the purchasing agent between the engineering department and the suppliers of materials. Most suppliers have sales engineers who can be of real service to the designing and production engineers of their customers and it is a mistake to prevent direct contact between them. In many cases the sales engineer from his wide experience can make suggestions that save time and money.

Inspection departments in some plants seem to think that their job is to reject as much material as possible. Every unnecessary rejection costs money to the supplier and eventually to the buyer, because all costs must sooner or later come to the customer.

Duplication of reports also causes delays and frequently costs money on both sides. It takes time for the reports to be read and passed by heads of different departments, and when for

FIG 125—Too much system will strangle the best engineering department.

some reason one department head misses a report, the placing of orders for much needed material is seriously delayed. Parts are frequently lost or mislaid in inspection departments, which means delay for both user and supplier.

By keeping systems as simple as possible and placing responsibility on the men involved, work will progress faster and there will be fewer annoying and expensive delays. Progressive engineers welcome the advice and experience of sales engineers and should have free contact with them. The job of the purchasing agent is to buy at the best terms possible after the

engineers have decided which machine or material is best for the job in hand. In Fig. 125 is an artist's idea of too much system.

MISCELLANEOUS EXPENSES

Cost of Mistakes.—There are few shops where the cost of mistakes is not much higher than many realize. Some of these mistakes are

In taking orders.
In ordering materials.
In reading a blueprint.
In picking the wrong drill.
In running out of needed stock.
In failing to make the workman understand.
In not knowing the degree of accuracy required.

And there is a host of other items that all add to the cost of overhead.

While we can never be 100 per cent right, a realization of the common mistakes can be of help in reducing them. Many mistakes are made in trying to save a little time, and these often prove an expense rather than an economy.

Individual notions and prejudices are also responsible for many minor leaks in shop expense. Cutting oils or compounds are an example, especially in the small shop. Some men feel that only lard oil will give a smooth thread, others want fish oil or other special lubricant. In one case the toolmaker could only get smooth work with a certain brand of oil. It was a trade name product and quite expensive. He was a good man but the boss felt it was largely his imagination. So one night he switched the oil, putting the new oil in the can with the pet label. The man never knew the difference and the work continued to be O.K.

Hardeners, too, used to be very fussy about their cooling mixtures. One old chap used to buy his own ingredients for the hardening bath, partly in one store and partly in others. He punctuated the shopping tour by slipping into a saloon between purchases and mixed the bath in secret. One day he visited too many saloons and didn't show up the next morning. A young man who had had some experience took over the hardening job and succeeded without any secret formula.

False Economy.—It is sometimes very expensive to save a few cents on oils, drills, files, or other supplies. Net costs are what count—checked over a sufficiently long period. In many cases a small saving in material may cost much more in labor required to machine it. Careful consideration of all factors involved, without undue haste and with good judgment of men and materials, makes for real economy.

Price alone is never a safe guide in selecting materials, machines, or men. Frequently the cheapest in first cost may prove very expensive. Castings full of hard spots are expensive at any price. On the other hand, a high price does not ensure the best quality for your particular job. This applies particularly to materials, oils, small tools, reamers, drills, and taps. Here the reputation of the maker is of utmost importance.

On the other hand, there are a number of simple, low-cost machines on the market that give excellent satisfaction in certain shops. A small inexpensive bandsaw does nearly all the work in one good-sized pattern shop while a large and more expensive machine stands idle except for jobs beyond the capacity of the small saw. The small machine is much more convenient to use and the men like it.

The same is true of some drilling machines and even of lathes for ordinary work. But for really accurate drilling or turning only the best is good enough. On the other hand, it is not economy to use a precision bench lathe on rough machine repairs, no matter how sturdy the lathe may be.

Spoiled Work.—Spoiled work is one of the serious problems in any shop. It not only costs money in wasted time and material, but it also interferes with delivery to the customer. This is not only embarrassing if the work has been promised, but may carry a penalty for not meeting a delivery date. Then, too, it seriously affects future orders.

There are many causes for spoiled work, and these should be carefully considered. They vary from ignorance or lack of instruction to pure cussedness. But it is rarely safe to jump at conclusions.

It is most important that instructions are thoroughly understood. Some men fear to appear ignorant and say they understand directions without fully appreciating what is meant. This is more likely to be the case where either the foreman or the

worker is not fully conversant with the language or the practice of the shop. It is a failing with many to try to make it appear that they know more than they do. On the other hand, some busy foremen assume their instructions are fully understood, whereas this is far from being the case.

Machine faults due to loose bearings, to worn feed screws, or misalignment of ways and spindles may be responsible. If so, it is the fault of management in not providing machines and tools of sufficient accuracy for the work to be done. Moreover, workmen should be impressed with the fact that it is their duty to report any such defect promptly so that it can be corrected.

All of us make mistakes, but the average man does not make the same mistake twice. So, before firing a man for a mistake, it is well to consider whether, as he is not likely to make the same mistake again, he is not safer than a new man. Continued mistakes point to carelessness or lack of ability. They make it necessary to put the man on a job requiring less ability or get another man.

While this may not be considered as a part of "overhead" by some authorities, the costs entailed by mistakes have to be accounted for apart from direct production costs.

Standardization of Shop Supplies.—Standardization of shop supplies is necessary in large shops and is usually advisable in small shops as well. Simplification is especially important, particularly with reference to the variety of steels and other materials used.

Heat-treatment has become standardized for the different grades and kinds of steel. But the small shop will find it best to select as few grades as will meet its requirements and stick to them until there is good reason to change. A good average efficiency is better than having too many kinds, with possible failure in heat-treating.

Similarly there should be as much simplification of screw and bolt sizes as possible. This also applies to strip and sheet steels and to other materials. It is frequently cheaper to cut down a bar of steel or to trim a sheet than to carry too many sizes in order to have them for an odd job. Both the cost of storage space and of handling, as well as the money tied up in the material, must be considered.

The same applies to small tools such as drills. It was for this reason that the Standardization Committee of the A.S.M.E., in connection with many large users, formulated the new simplified list of twist-drill sizes. This list is simply a suggestion of preferred sizes which cover the range of general use with less than half the total number of drills formerly listed. It is uneconomical to skimp on the number of drills and other small tools. It is poor economy to waste time because of a lack of the tools needed. Have plenty of the sizes generally needed and fewer of the odd sizes so seldom called for.

Averaging Shop Materials.—Small and medium-sized shops are faced with the problem of selecting materials that will be satisfactory under average conditions. Mass production, such as in the automobile industry, permits the use of a wide variety of steels selected for qualities that meet the demands of each part. In a small shop, however, both the cost of carrying stocks of many kinds of steels and the different heat-treatments necessary make this prohibitive. It is necessary to select materials and tools that can be used on a wide variety of work.

Where a shop does its own heat-treating and has limited equipment, steels must be selected that can be handled by it. Nor can even a good tool hardener be expected to get best results when he must change his methods too frequently. It is generally advisable to select materials and tools that will answer average conditions and not be induced to change until satisfied that the new material will meet average conditions even better.

The same thing applies to both cutting tools and cutting oils and compounds. Certain brands of high-speed steel may give somewhat better results than the one being used. But unless the new brand *averages* better than the one being used, it is probably unwise to change. Most shops have occasions when carbide tools will pay even, at the same cutting speeds, either because of the hardness of the material or the cost of changing the tool setup. It is often profitable to have a few carbide tools for such emergencies, even if not for general use. On the other hand, some job shops find that carbide tools pay on average work if the machine equipment will permit the higher speeds necessary to secure more than average results.

New materials should always be considered and the claims made for them looked into carefully. But it does not pay to be

stampeded into changing steels or other materials that have been satisfactory because newer steels have come into the market. Until you are satisfied that the new product will give better *average* results than the old, it is wiser to stick to the brands which have served you well in the past. When you become satisfied that the new materials will prove economical on your average work, the change should be made, but not before.

AN OUTLINE OF THE FORD POLICIES

The following outline of the Ford policies is by John Younger, a professor of industrial engineering at the University of Ohio. He sums up the advantages of the organization in the 15 points given below. Some of these may be applied in many smaller plants.

1. Concentration upon a single product.
2. Keeping each article distinct.
3. Extensive use of conveyor systems.
4. Subdividing work so that each worker has only one or very few operations to perform.
5. Providing the required quantity of material of the specified quality at the required time and place.
6. Assigning a definite amount of work to each man to be done in a given time.
7. Wage payment on the straight day rate.
8. Acquisition of sources of raw materials.
9. Reduction of inventories of materials in stock and in process.
10. Foregoing the taking of intermediate profits on processes between raw materials and finished product.
11. Keeping materials and parts in rapid motion to assure quick turnover.
12. Using machine tools that give the lowest production cost and require the least manual control.
13. Employment of machines that perform several operations simultaneously with the same amount of labor as for one operation.
14. Sending machines to the overhaul shops at standardized periods.
15. Recognition that the obsolescence factor is more potent than depreciation of machines by wear.

The huge plant is in reality a multitude of small shops, each complete in itself and making but one unit or one small assembly. The machines are placed with reference to the sequence of operations rather than grouped into departments for turning, milling, etc., as in the old method. A heat-treating furnace is between two machines if the operation requires heat-treating at that point. The timing of the conveyors sets the pace for workmen which eliminates any advantages piecework may have had without them.

SHOP BOOKKEEPING

Shop bookkeeping may be said to include all "paper work" used to keep track of materials, tools, work progress, and labor. In the early days of so-called "scientific management," the systematizers ran wild in devising forms to record all sorts of details. The paper work required large numbers of clerks and cost a lot of money for both printing and salaries. Now, fortunately, there is an earnest effort to reduce work of this kind to a minimum. As the manager of one well-known concern said, "When I first tackled this job, I spent a lot of time and money making forms to check the work at every step. I found much of this was foolish because some of the work was so large that you couldn't lose it if you tried. Now I'm devoting a lot of time eliminating most of the forms I then thought necessary."

Essential Records.—Records are of course necessary to know how much raw material you have on hand, how much finished product, how much work in process, and what they all represent in cash. Time tickets for different jobs, checks or slips to show who has tools from the tool crib, job tickets to show where different work is to be done and what it costs, as well as many other records in more or less detailed form, are needed. Details of these records will be found in other sections.

It is also very necessary to know where to find spare parts for machines already built and patterns for those that may be needed. But all records should be as simple as possible. The problem of setting prices on parts of machines, especially those which are no longer in production, will be discussed later.

Charges for Repair Parts.—Setting the price of parts of machines to be used for repairs should be carefully considered. There are several points to be considered beside the actual cost

of the piece itself. The cost of handling the order, from its receipt to the shipping of the part, is frequently more than the value of the part itself. This is particularly true of small and inexpensive parts such as special bolts and nuts. Some concerns have found it advisable to make no charge for parts on which they would not be justified in charging over one dollar. They feel that the good will is worth enough more than the cost of antagonizing customers by a seemingly high charge in order to make it worth while.

High charges for parts of machines that may require replacement antagonize customers. This is what led Ford to revise his parts price list to its very low level many years ago. Excessive prices for repair parts influence buyers of new machines more than many seem to realize.

On the other hand, the cost of storing and handling orders for repairs must not be overlooked. This is particularly true of parts for machines which have become obsolete. In such cases the spare parts have to be handled or counted at each inventory, they occupy valuable space, and they require some care. All this should be paid for by the customer.

Some advocate adding to the cost each year a part is kept in stock to cover the costs which have been mentioned. They also suggest that after a given time the piece be declared obsolete and charged for as though it were made to order, even if it happens to be in stock. Makers of such apparatus as fire engines have to carry a large stock of old parts since these machines are long-lived and breakdowns must be repaired as quickly as possible.

The whole question of spare-part prices should, however, be carefully studied from both the makers' and consumers' viewpoints. The costs of carrying and handling also must not be overlooked.

HANDLING EMERGENCY ORDERS

Emergency orders for standard equipment, such as come in time of war, present a difficult problem for management. Handling them in its own shop means adding one or two shifts or increasing manufacturing facilities. Adding more shifts has the advantage of utilizing the machine equipment more hours per day but involves the problem of supervision and of keeping the work going smoothly from one shift to the next. Adding to

plant and equipment is generally considered as a last resort, for it remains as overhead after the emergency is over.

Another alternative is the hiring of work done by other shops. And this is one that should be carefully considered by all makers of machines that are likely to be used in large quantities in emergencies. Machine tools are a case in point. Some builders of machines of this kind find shops as conveniently located as possible which can make parts of their machines in a satisfactory manner. In some cases they contract with these shops for complete units, in much the same way that automobile builders have transmissions made by outside companies. Some, on the other hand, contract with other shops for the building of their entire machine. But there are several points that should be carefully considered in this connection.

Where only parts or subassemblies are made in other shops, these all come to the home shop for inspection and assembly. In this way it is possible for the builder of the machine to assure himself that the quality is being maintained. This is very important since the purchaser of the machine looks to the builder for the perfection and performance that are expected. It also has the advantage of not encouraging future competition.

KEEP GENERAL INFORMATION AVAILABLE

Every shop should have several books of reference on matters that pertain to shop work. While most mechanics are familiar with the usual sizes of drills and taps, it often happens that a special job comes in and time is lost in finding out just what the customer wants. Taper shanks for tools, for example, are not entirely understood in all shops. Most shopmen know that Brown and Sharpe tapers are $\frac{1}{2}$ in. per foot and that the Morse taper is $\frac{5}{8}$ in. per foot. At least those are the nominal tapers. In reality both tapers vary somewhat from these angles, presumably due to lack of accurate measurements when the tapers were first established. It is sometimes very necessary to know exactly what each taper is, and this can only be found in up-to-date books of reference.

There is also a new taper of $\frac{3}{4}$ in. per foot for larger sized shanks, which was adopted by the Taper Shank Standardizing Committee. This is the same taper as the standard pipe thread. When a job comes into the shop with some of these tapers designated,

it saves time, money, and prestige to know just what the customer has in mind.

Spindle noses of both lathes and milling machines have also been standardized, as have T slots for machine tables, bolts for these slots, and numerous other parts of modern machines. When chucks or tools are to be made for these machines, the shop that has all these data available has a great advantage over those which have not kept posted on such developments.

Up-to-date mechanics keep one or more standard mechanical handbooks in their kits not only for this information, but to save them time in figuring threads, angles, layouts for jig borers, and similar calculations. Every machine-shop office also should have a fair collection of such books available. They will save time and money for both the boss and his men.

Shop Visitors.—Shop visitors are a problem that each shop must settle for itself. To large plants that make a product for public sale, such as the automobile factories, plant visits by the general public are an excellent advertisement. The same is true of many other consumer-goods industries. The average machine-shop is a different matter.

Generally speaking, the greatest consideration is the time it takes to show a visitor through the shop. A mechanic or engineering visitor will frequently give the shop one or more pointers that will more than repay for the cost of the visit. It is generally believed that a shop gets more information than it gives to others, simply because of the number of visitors. Exclusion of proper visitors usually keeps more information out than in.

Shop secrets are few and far between. Given a problem to solve, a dozen mechanics will usually solve it in ways that are about equally efficient. The methods may differ because of the men's previous experience, the shop equipment available, or the skill of the average employee in the shop. And having adopted a method that is satisfactory, both pride and circumstances tend to prevent copying the other fellow's method.

Free Access to Plants.—Automobile progress has been largely due to a free interchange of ideas among the different plants. Not only have patents been pooled to a great extent, but shop methods are open to rival companies in nearly all cases. Experimental departments are usually closed to all but a few in the

plant itself, but general machining or handling methods are an open book in most cases. Engineers from one automobile plant visit other plants with great regularity, and the free flow of ideas is largely responsible for the many improved methods now in use.

In the same way the publication of shop methods by our technical periodicals has done much to raise the efficiency of the shops all over this country and abroad. Superintendents and managers of large shops are free to acknowledge the many good ideas they have secured from articles in technical and trade papers. In exchange they give out many of their own developments in the belief that their direct competitors probably know of them already and that they may give ideas to others that will help the industry as a whole.

Most of this benefit comes from adapting an idea or method to individual problems. Direct copies seldom find a place owing to differences in condition. Unless one can see applications of an idea to work that may be entirely different in character, he gets little from studying the way in which other shops do their work. Here again the technical paper plays its part, for the editor, from long observation in a wide variety of shops, can point out applications that are not always apparent on the surface.

The average intelligent shop manager finds it advantageous to permit visitors who have a real interest in his kind of work. If secret ideas are stolen, it is seldom by the casual visitor but by someone directly interested in the particular line of work. The usual way is to get a job in the shop and so find out as much as possible about the methods used. But cases of this kind are few and there is little to be feared from the visitor who is really interested and who tells you who he is. In most cases it pays to have visitors who are not idle sightseers. They spread your reputation for good work and often bring business that you would not otherwise have received and that you never can trace.

ANALYZING A SHOP FOR MODERNIZATION

Those who want to improve their plants but are not familiar with the methods of making an analysis will find the suggestions of M. G. Godschall of the tools and methods planning department of the General Electric Company, in the *American Machinist*, helpful in many ways. Their plan was as follows:

1. A detailed study was made of the operations performed on the various parts of a motor from the time the raw material entered the department until it left in the completed motor. This was accomplished by making process flow charts of each part; recording each time the piece of work was acted upon by some force, with the source of that force, whether manual or machine; the type of machine; and the distance traveled in feet, as well as the means of conveyance.

2. Floor plans of existing layout were next made to a scale of $\frac{1}{4}$ in. = 1 ft. showing the detailed outline of each piece of equipment and its physical location in the department, and any special features such as type and size of driving motor, special foundations, etc.

3. With the above list of operations and equipment an analysis of the existing department was made.

a. By drawing on blueprints of the floor plans, lines showing the path of travel of each piece of apparatus from operation to operation through the department. A different colored crayon was used for each type of apparatus.

b. A study was then made of each individual operation to determine if a better way could not be found to do the work. This study was made with the help of the job foreman, the department superintendent, the tool designer, and the apparatus engineer.

4. With the above information machine capacities were next determined. Owing to the variety of motors made in this department the individual time required to perform a given operation differed greatly for each variety, and the fact that similar operations for various classes of apparatus were performed on the same machine necessitated the determination of a weighted capacity. This was determined as follows: The production records for several years past were studied for each class of apparatus, and from these an average weekly production was determined. A chart was then made for each operation, showing the machine used and the number of hours required each week to produce the part for each variety of motor made on that particular machine. The hours were obtained by multiplying the numbers of pieces to be made per week by the time required per piece, allowing a percentage for lost time. The time per piece was taken from existing time studies, for operations which were to be maintained and from estimated time in cases where it was decided to adopt new methods. The summary of these charts determined the number of machines required for each operation. Owing to the fact that many special motors were constantly being made, and that the ratio of varieties differed to a certain extent from week to week, the actual calculated capacities were increased in certain instances.

With the foundation thus prepared they were ready to start the structure.

The first step was to estimate as nearly as possible the total area which would be required by each subdivision of the department. A block layout of the department was next made placing each subdivision in the most efficient relation to the others in regard to progressive flow of material and shortest distance of travel. The only limiting features of this plan were the walls and permanent fixtures of the building in which it was to be set up.

After a satisfactory general plan had been arrived at, they proceeded to make detailed layouts of each subdivision. Templets were made to a scale of $\frac{1}{4}$ in. = 1 ft. for each piece of equipment, including benches, tables, conveyors, etc., and using the area arrived at in the general plan. Various arrangements were tried until one was found which seemed to possess the greatest possibilities for satisfactory operation. Careful consideration was given to the selection of the proper handling equipment, as well as the relative arrangement of the various pieces of equipment for the most efficient set of motions. Each plan so made was explained in detail to the job foreman, the department superintendent, and the supervisor of stock and production.

Factory Cooperation

Many valuable suggestions were thus obtained and incorporated in the plan. This plan of consulting the factory men had another very desirable feature. It created in them an interest in the new plan before it actually was put into effect and produced a feeling of cooperation that was greatly appreciated when the installation actually was made. For this reason a suggestion from the factory was always adopted if possible.

After a satisfactory detailed plan was arrived at, a tracing was made of it, from which blueprints could be made for installation purposes. Designs were also made for new equipment and conveyors. A master layout was made to a scale of $\frac{1}{8}$ in. = 1 ft. showing the whole department in detail. After all plans were completed, detailed costs and economies were obtained and an appropriation requested to cover the cost of the entire move.

As finally worked out the direct-current motor department occupies the entire second floor of the motor building. This floor is approximately 800 ft. long, extending from north to south, and 80 ft. wide, with three towers on the east side, each containing a stairway and a freight elevator.

The plan provided for an aisle along the extreme east side of the building extending along the wall from the north to the south tower, which left available the remaining width of the building as a free area for arranging of equipment and permitted the use of conveyors between machinery, stock and assembly areas without having to cross aisles.

The department was divided into four major areas, starting with the north end of the building.

1. Mechanical Parts of Rotating Element.
   a. Shaft.
   b. Core.
   c. Commutator.
2. All Electrical Parts, Rotating and Stationary.
   d. Armature-coil winding.
   e. Armature winding.
   f. Armature and field coil, baking ovens, insulation stock.
   g. Field coil.
   h. Armature finishing.
3. Stationary Mechanical Parts.
   i. Leads—brush rigging.
   j. End shield.
   k. Magnet frame.
4. Accumulation of Parts and Finishing Operation.
   l. Stock and assembly.
   m. Test.
   n. Paint.
   o. Crate and ship.

Partitions 8 ft. high were placed between adjoining sections to prevent chips or metal parts from damaging the electrical elements.

In general, all movement of material in the department is: up the elevators on trailer trucks, south along the main aisle to the proper area, then west through the processing operations to inspection, and finally south on the conveyor along the west wall to stock assembly test and paint. Crated motors are taken down the elevator in the south tower on trailer trucks to the shipping department.

Throughout this plan mechanical handling has been used wherever possible, thus keeping work in process off the floor and moving according to a carefully worked out schedule. Conveyors have been used almost entirely for transportation of material in process and finished material. The types of conveyors in use are as follows:

1. Gravity roll.
2. Live roll.
3. Power belt.
4. Power apron.
5. Overhead monorail.
6. Overhead power chain.
7. Floor-operated overhead electric crane.

A trailer-truck system is used to transport raw material from the contributing departments up the elevators to the various processing areas.

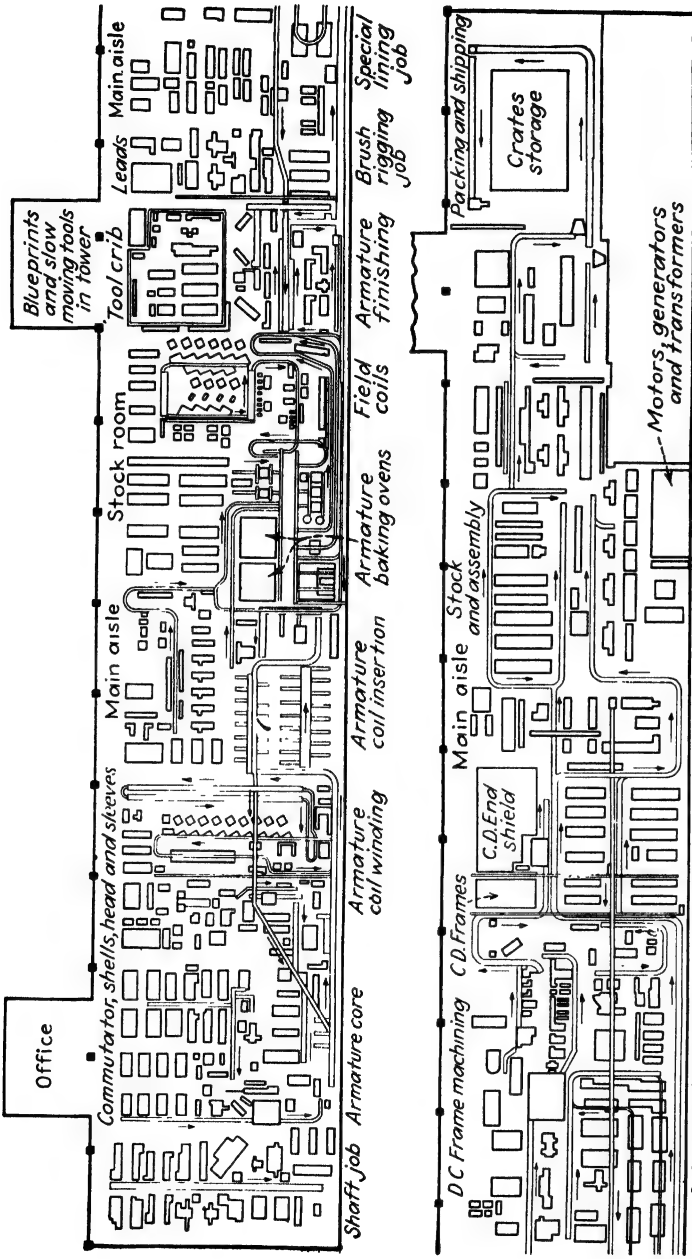


FIG. 126.—Relocations of machines that helped modernize production methods.

All stock areas are adjacent to the aisle, and space is provided for trailer trucks at each area. Space is also provided for trailer trucks opposite each elevator, so that there is no excuse for violation of the strict rule that the aisle must be kept clear.

Shafts are made in economical lots, as far as possible, to avoid excessive set-up costs and are stored in metal racks adjacent to the inspection bench. Special shafts are made as required but are handled in a manner similar to the standards. Shaft stock is delivered to the semi-automatic turning machines on skid platforms. After turning, the shafts are placed in a tray which operates on a double width section of gravity roll conveyor. This conveyor extends through the job past the milling and grinding operations to the inspection bench. The tray is designed to hold a quantity of shafts which can readily be handled on the conveyor and the double width conveyor permits the shunting of rush orders around the normal production.

Core punchings are brought from the punch press department in another building via the trailer truck system and transferred to a series of stock bins adjacent to the aisle. Punchings, too, are made in economical quantities as far as possible, but the production is so scheduled that only a few days' supply of punchings is in the bins at any one time.

Other details of the motors, such as commutators, shafts, armature cores, and the like, are handled in a similar manner. Continuous overhead chain conveyors are used for such parts as coils, largely to keep them up in the air away from possible damage. These conveyors also act as storage space and obviate handling costs until the parts are needed. A plan of the floor with the machine layout is seen in Fig. 126. The arrows show the flow of material and indicate the almost continuous flow of work without backtracking.

As a result of this planning and rearrangement, the department now occupies but half the floor space formerly allotted to it.

DEVELOPING A PRODUCT

John A. Honegger suggests a method of analyzing a new product in order to see its chances of success before starting manufacture. He considers that

. . . from the inception of the idea to the finished product, there are at least 38 steps that must be considered, as shown in the accompanying chart, Fig. 127.

Five divisions of this chart indicate in detail the time, money, and effort involved before a patentable idea is transformed into an acceptable and salable product.

Patent survey, the first division, involves a search of previous patents to establish priority before spending any further effort. If the idea is

Steps in Product Development

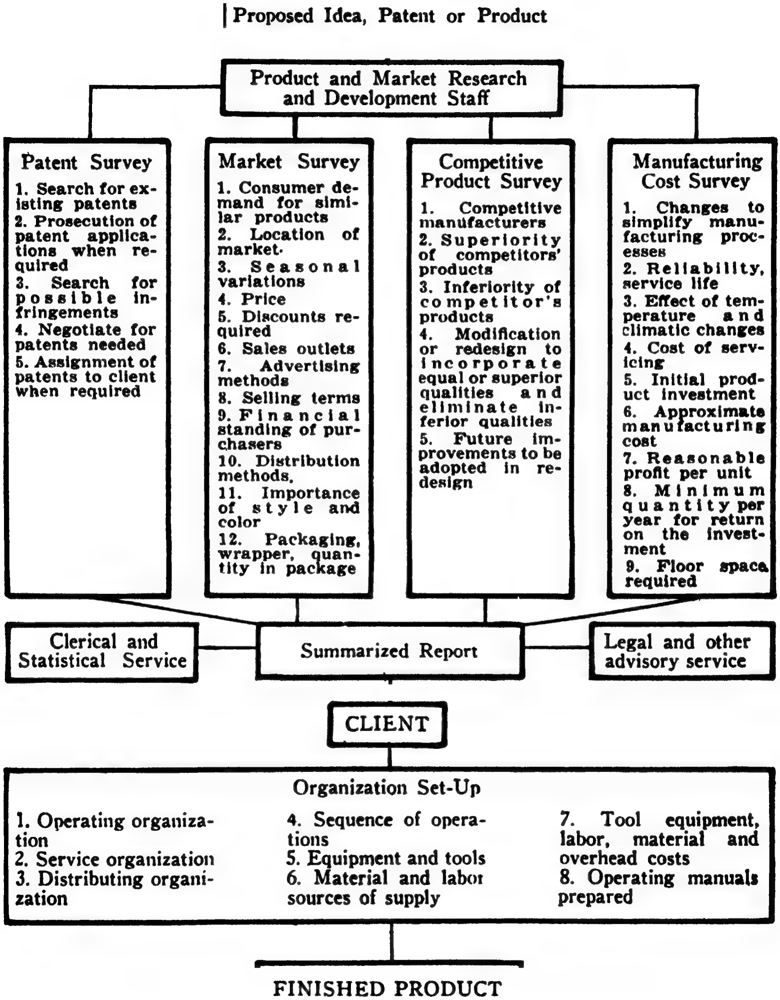


FIG. 127.—Organization chart for manufacturing plants.

only an improvement, it may be necessary to purchase existing patents to reduce the possibility of infringement.

Information under market survey is considered before product survey to provide data for the manufacturing organization. For the maker is interested in what to manufacture, where products can be sold, the selling price and quantity.

Competitive product survey is essential since competitors also desire to sell their product. Competitive products must be examined for advantages over the new product, and all possible improvements incorporated in the new device.

If the manufacturing cost survey is favorable, the producing organization is set up, and the product is started on its way to the consumer. The future of the product is assured if every step has been checked by this careful procedure to eliminate chance, the greatest factor in industrial suicide.

CHAPTER 10

FOREMEN AND PERSONNEL RELATIONS

The foreman's job depends both on the size of the shop and on the kind of management at the top. It varies from being a clerk to keep shop records to what is virtually the manager of a small shop. In between these extremes come the foreman whose sole job is to push production at all costs, others who are supposed to browbeat the men into accepting whatever the management prescribes, and those who are simply buffers between the men and management.

The foremen who are really most valuable are those who can make the men and the management see and understand each other's problems. They must know enough of human nature to handle different temperaments without undue friction. Some men react best to stern reprimand. It jars them out of a rut. Others can be handled much more effectively by gentler, even by indirect methods. This is not playing favorites as some seem to think. All men cannot be handled in the same way and secure the best results. But all must be treated with absolute fairness in every respect.

In some small shops the foreman is one of the busiest men. He must look after orders, keep them going through the shop, instruct men on new work, help them out of trouble when they get stuck, and keep time and costs. All in all, he has his hands full. And all too often he is not appreciated by either management or men.

Familiarity between foremen and men depends largely on the temperament of the foreman himself. Some men have a natural dignity that makes it difficult for any but their closest friends to call them by their first names. This is not being "high hat" or putting on "dog." More often it is diffidence or a natural reserve that he would gladly dispense with.

Other foremen maintain equal authority and respect when even the apprentices call them Bill or Jack. It all depends on the

temperament of the individual. Some secure results by heavy bossing, others by working with the men. Generally speaking, however, the latter type are liable to do much of the actual work and not have time for their other tasks.

In most cases the foreman who apparently does no work himself, gets out the most production. Except in cases where the foreman is supposed to run a machine in actual production—or be a straw boss—he should rarely do production work himself. He is worth more in directing the work of others.

Some shop owners pat the foreman on the back when he gets them out of a hole and then bawl him out the rest of the time. When things go smoothly, they forget he exists. They frequently make him a foreman to avoid paying overtime. When the men kick too hard at some office rule they blame the foreman as though he were responsible for it.

Other owners pick a good man for foreman and treat him more like a junior partner. They pay him a fair monthly wage, which includes holidays, sickness, and vacation. This sort of foreman works as though the shop is his own. He learns his men and their good and weak points and gets more work out of them by so doing. He gives the men a square deal and insists on getting a fair production from them.

This kind of foreman can save a lot of money for the owner and get the best sort of men in the shop.

HIRING AND FIRING

Personnel Director.—Many large concerns have learned that the personnel director is one of the most important men in the organization. The larger the concern the more difficult it is for the management really to know anything about the employees. So the personnel director's job is to do this for the management.

The successful personnel director must first of all understand human nature. Many men applying for a job are ill at ease for several reasons—anxiety for their family or for themselves, disconcerted by unfamiliar surroundings, self-consciousness. For this reason it is well to have a small private room in which the applicant can talk face to face with the interviewer and be more at ease than in a room with others.

Some directors keep a few fine tools on their desk, such as a micrometer, a vernier, gage blocks, and a few plug gages. Men who are a bit nervous get a feeling of the shop by handling such tools. And the way in which they are handled gives a very good idea as to their familiarity with them. Such tactics often give a better idea as to a man's ability than he can tell in words, or show on questionnaire.

The Application Blank.—One fault with many employment offices is the length of the application blank and the questions it contains. Most of these blanks are much too long and the questions are too personal, if not actually impertinent. There is little excuse for these on any application blank. Questions that deal with a man's religion, politics, or bank account should not be asked. It would be much more logical for the employer to state his own financial standing. Ability, reliability, and the capacity of working with others are much more important.

The folly of relying on such questions is shown by the experience of the employment manager of a large concern. The applicant filled out a most satisfactory blank and was put to work. In some way it came out that many of his answers were untrue. He belonged to no church, had no money in the bank, did not own his own home—in fact, most of his statements were untrue. The employment manager was furious and demanded his discharge. The foreman refused. Whether the man had lied or not, he was the best man in his department. He was short of good men and the "big boss" was pushing him for production. So why should he lose the best man he ever had just because that man had lied to get the job?

Called into the office the man said, "I've been after a job for weeks. I've filed application blanks till I know them by heart. I've learned the answers you employment managers want, so I put them down. I knew the answers were not true. I also knew the questions had no bearing on the work I could do. I knew I could make good if I had a chance, and I have. So I lied to get the chance. Why not? I'd do it again. If you don't want men to lie stop asking them questions that have no bearing on the work you want done. Then there would be no temptation to lie."

He kept his job. His answers should be well remembered by all who prepare questions for applicants for work.

WAGE-PAYMENT PLANS

Between hourly wages and complicated bonus systems, there are many variations in wage-payment methods. They vary widely, from merely considering the time spent in the plant to depending entirely on the amount of work produced. The simplest wage plans are the hourly wage and straight piecework. The natural object of the worker is to secure as large a yearly income as possible, whereas the employer wants to reduce labor cost on his product to the lowest point consistent with quality.

The hourly or weekly wage is in general use in most small shops. Work varies too much to permit any other system. The workman requires a steady income to maintain his family just as the employer must have sufficient income to keep his business running. Uncertainty affects the peace of mind and frequently shows in both quantity and quality of work. This factor is largely responsible for the proposals for a yearly wage. The yearly wage is used in a few plants now, and many consider it a vital problem for employers to consider in the future.

Piece rates on repetition work enable the worker to earn in direct proportion to his ability. The employer also has a definite labor cost for each operation and a definite cost for all the direct labor on the finished product. Some workers are exceptionally fast and can earn much more than others under the same conditions. Theoretically each man should be permitted to earn all he can, but in practice this does not always make for harmony and smooth operation in a shop. Where competition is keen, the fast man's pace has been taken as a standard and piece rates cut until the less skilled could not earn a bare living.

Halsey Plan.—To prevent this condition and at the same time preserve the competitive feature of piecework, Frederick A. Halsey devised the premium plan which bore his name and which was widely used for many years. It has been modified by many others and still persists under various names. His method set a time limit on each job and a portion of the saving, usually half, went to the man, the other half to the shop. It was virtually piecework with a check on rate cutting because management could see that they benefited directly by the increased production.

Taylor System.—Frederick Taylor devised one system in which the man got an increased price per piece when he exceeded the

standard output. This was based on the very logical idea that as increased production decreased the overhead by securing more output from the machines, the extra production could be paid for at a higher rate, and so make an added incentive for the worker. This never became popular because the average manager looks only at production costs regardless of the effect of increased output on overhead.

This was opposite to the Halsey plan in theory, for while Halsey virtually reduced the piece price after the quota was reached, Taylor increased it. If, for example, the man got 30 cents each for the first 10 pieces per day, he might get 35 or even 40 cents per piece for all over 10 pieces.

The Rowan system in England, on the other hand, had a reduced scale of piece prices as the output increased so that the worker could never double his wages regardless of his production.

Many systems have been devised which try to avoid the pitfalls of piecework by using different terms and by counting efficiency in percentages instead of output per piece. They are all based on increasing the output per man and on lowering direct labor costs without antagonizing the worker. All depend on some sort of time study of the operator at his work, and all have the object of reducing lost motion and time spent on the operation.

Time studies made by inexperienced men and their injudicious application have been responsible for many labor disputes. Only the utmost fairness in making time studies and a square deal in their application should prevail.

One of the greatest mistakes in all cases of this kind is the assumption that management possesses all the intelligence in the plant. That was the great weakness of Taylor and his followers, who tried to make a robot of every machine operator, whose instructions outlined in detail every movement from start to finish. This not only antagonized every good mechanic but prevented helpful suggestions that mean so much in the average shop.

Every good mechanic has ideas that can be of value to management, as is proved by the success of suggestion boxes in many places. Some of the ideas may be crude and need refinement, but many good, basic ideas originate in the shop.

Bonus System.—Bonus systems are largely the outgrowth of the Halsey premium system. Harrington Emerson, Charles Bedaux, and many others have installed systems of this type. In too many cases they only pay attention to the speeding up of the workers rather than encourage new methods that will reduce costs without increasing human labor.

Group bonus works well in some shops, for in many cases the output of a department depends on the co-operation of the men in the group rather than on the work of individuals. In such cases the bonus is divided among the group. Sometimes this is an equal division, and sometimes the bonus is divided in proportion to the salary of each. This is on the assumption that the co-operation of the higher paid men in the group contributed more to the result than the work of the less skilled.

One result of group bonus is to reduce the amount of supervision necessary. If one laggard reduces the earnings of the whole group, it is in the interest of all to see that each man does his share. In this way each good worker makes it uncomfortable for those who lag behind. In cases of illness, or when a man is below par, it is not uncommon for the others each to do a little more and so keep up the quota for the group.

The importance of the group rather than the individual is indicated by the extensive abandonment of piecework in the automobile plants which now pay an hourly wage. In shops where the work goes from machine to machine by conveyor, the extra fast man is of little use, except as an example to the rest. In reality the conveyor speed sets the pace for all, and this must be adjusted to the slowest man in the group. Anything that will speed up the slower men helps production more than a few very fast men.

Whatever the method of payment some basis must be established that will be fairly satisfactory to the men, whether it be hourly, piece rate or any other system. All time studies should be made openly and by men who are familiar with the work and the conditions surrounding it. Detailed study of every operation, such as picking up the work, putting it in the chuck, tightening the chuck, setting the tool, etc., has no place in the average shop. The complete operation as performed by a fairly good man is all that is needed as a standard.

There are places where the photo-motion study inaugurated by the late Frank Gilbreth and his wife, who still carries on, can be used to advantage. But they must be used with more intelligence than is generally shown by the average efficiency engineer to be of greatest value. It is nearly always a great mistake to try to make all workers conform to a given sequence of motions. If the net result is satisfactory, the exact motions are not important. In fact, the less we try to make men into robots, the better. In many cases the man at the machine will find better ways of doing the job than even the experts have worked out. The more individuality we keep in the men, the more management benefits through their initiative and interest in the work.

A Definite Contract Wage Plan

A. L. DeLeeuw proposes what he calls a "definite contract" plan based on a definite understanding between employee and employer, and presupposes certain definite conditions of machines, tools, and work piece. It bears the relation of buyer and seller. It instructs the man as to how he can earn a definite amount of money, but it leaves him free to earn it any other way. It permits the employer to change the contract price, but only when some new condition has arisen, such as new tools or machines, and then only to the extent that the contract time has been affected by such a change. In a few words, it is elastic where it needs to be.

Definite Instruction Sheet.—The main element in this system is the *instruction sheet.* This sheet is given to the man when he starts a new job. He finds on it all he needs to know in regard to the details of the job. As an illustration, if the job is to be done on a machine tool, he finds on it the nature (and, whenever possible, the number) of the machine, the nature of the jig or fixture to be used and the various tools required for the various operations to be performed. The job is dissected into its elements. If there is more than one cutting operation, each of these operations is treated by itself. Speeds and feeds are given and instructions are given as to how these feeds and speeds may be obtained. Time is set for each element of the handling operations, such as chucking, unloading, and setting of tools.

As it is not possible to avoid slight differences in the cutting capacity of various tools of the same shape and material, or

slight differences in the machinability of different lots of work, a certain percentage is added to the cutting time. A further percentage is added to the total time for other reasons that will be mentioned later. In addition to all this, there is a certain amount of time given for the setup of the machine. In this way, the total time allowed for a lot of pieces becomes the setup time plus the time allowed per piece multiplied by the number of pieces in the lot.

Can Use Own Method.—The time allowed per piece is called the *standard time.* It is assumed that the man can make this time if he follows the instructions given on the sheet. However, the man is not compelled to follow the method indicated. He is free to do the work in any way he thinks best. His wages are increased by a given percentage if he succeeds in making the standard time. Experience has proved that this should be about 33 per cent.

Notwithstanding that the time is supposed to have been carefully analyzed, it happens now and then that the man finds a better method and cuts the time to a considerable extent. If this happens, then there would be the temptation to change the instruction sheet according to the new method. This should not be done. The sheet should be changed, but it should not be given out so long as the inventor of the new method is willing to take the job at the old figure. If he leaves or is promoted, the new method becomes the standard one, but the inventor has reaped the reward of his invention so long as he cared to do the job. Though the man is free to follow his own way, he has no right to complain if he cannot make the time when he has not followed the instruction sheet.

Certain safety measures should be taken to make the system work to the best advantage of employer and employee. There is always a possibility that the time has been set too low, so that it is not possible for the man to make his bonus, however hard he may try. The necessary machinery must be provided to correct such mistakes and do it in such a way that the man shall not suffer by the errors of the time setter. It is for that reason, mainly, that a percentage must be added to the total of cutting and handling time.

When Sheet Is Corrected.—The man is supposed to report to the foreman or to some demonstrator, specially assigned to just

such cases, if he feels that it will not be possible to make standard time. If this foreman or demonstrator cannot do the job in, say, 15 per cent less than the standard time, the sheet must be corrected. The man should be given credit for all the time lost, with the addition of the bonus for that amount of time, for the system assumes that the man would make this bonus all the time if he is capable and attends to his job.

Generally speaking, standard time cannot be made unless tools and machines are in proper condition, and unless the material to be worked on is as it is supposed to be. A slipping belt, or feed clutch, or hard castings would spoil the game. It would do that whether the task and bonus plan or any other plan prevails. If, under the new plan, he is told by his instruction sheet that his cutting speed should be 70 ft. and he finds that 50 ft. is the best he can do, he has proper cause to report the condition.

Once the bad condition is reported, it is possible for the management to do whatever is necessary to get better castings in the future, and if that is not possible, to correct the instruction sheet. Such corrective relations between man and management are automatically maintained because the management has taken upon itself the duty to show that the time can be made, and even can be reduced.

One of the first things one discovers when the task and bonus plan is introduced is that the condition of the shop is not so good as it was thought to be. The reason why this should be so is not far to seek. In the past it was the management alone that took care of the plant. Under the task and bonus plan both management and men have a part in the work of keeping the plant up to date and in correcting any conditions that are not what they should be.

Every Man an Inspector.—Every man who has an instruction sheet before him becomes an inspector. To have reported small deficiencies in the past would have been kicking. He is not kicking at all, but merely looking after his own interests when he reports that he cannot carry out the instructions given him. The result of this continuous inspection by a great number of inspectors is that in a very short time the shop is in better condition than it ever was before.

It might be thought that there must be a large increase in broken tools and spoiled work, but the reverse is true. Experi-

ence has shown that both are materially reduced. He is careful not to do anything that may spoil his chance to earn the bonus.

Men and management are brought together as buyer and seller; or it might be said that the two enter into a definite contract. The acceptance of the contract is not compulsory on the part of the man. He has his day wage if he prefers this. Nor is it compulsory on the part of the management. It can let the man go along on day rates. However, once the management gives, and the man accepts, the instruction sheet, there is a mutual contract to which both parties are bound. The management must pay the bonus if the standard time is made; the man has no cause for complaint when he does not receive the bonus, because he did not succeed in delivering the goods.

Bonus Plans

Bonus plans of many kinds have been proposed and practiced for many years. Instead of a piece price for work done, there is usually a day rate, plus an additional amount if the work done exceeds a given minimum or standard. Halsey's premium plan was along this line and was very popular for many years. This, however, was applied only to the individual worker.

With modern mass production, especially those where conveyors are used, the output of each machine and man is timed to the conveyor. And this must be set at the speed of the slowest man in the line. Real efficiency is secured by increasing the speed of the slow man and so increasing the output from the group. Where conveyors do not control the output, many semi-automatic machines are set to perform their operations in a given time and the operator must be fast enough to remove the pieces of work as they are finished and replace them with new ones during the time allowed for the slowest cycle of the machine. It is for these reasons that piecework has fallen into disuse in the large automobile and other plants where the work is largely mechanized and depends more on the timing of the machines than on the man who runs it.

Even here, however, active co-operation between the men and between departments can increase the total output of the plant and give an opportunity for bonus plans to act as an incentive for more output. And in places where the individual bonus can be used to advantage, there is still opportunity for the group

bonus. In the Kearney and Trecker plant, for example, the bonus applies to everyone in the department when a saving is made in the output of that department. This includes apprentices, cranemen, and assistant foremen as well as those who run the machines.

An Incentive Plan That Is Easily Understood

A wage incentive plan which has worked successfully over a period of years is in operation at the plant of Brown & Sharpe Mfg. Co., Providence, R. I. It is a plan originated by the company and is free from the usual intricacies of most wage incentive plans. The ease with which the worker can understand it and with which he can figure his earnings is one of its most commendable features.

Fairness in its administration is another factor contributing to its success. Still another reason why the plan has proved satisfactory is that it is based on a sound rate setting policy in which the workers have confidence. If an operator complains about his earnings, his complaint is immediately considered and action taken.

Care has been taken to eliminate weaknesses found in many other wage-incentive plans. For one thing, men of considerable versatility and of exceptional skill are specially rewarded. Provision also is made for the older, less efficient employee so that he is adequately compensated without penalizing a department's costs.

The Unit Hour.—Actually the wage-incentive plan is a production-control plan for controlling direct and indirect labor costs. It provides a common unit for measuring the output of individual workers. This unit is the "unit-hour" which is a unit of work equal to the amount of good work that an experienced operator working at an average piece work rate of speed will produce in 0.83 of an hour, including time for rest. On this basis an experienced operator working at an average piecework rate of speed will produce 1.2 unit-hours of work per hour. A production of 1.0 unit-hours per hour pays the operator his hourly base rate of pay, and any production over this proportionately increases his earnings.

In other words, the wage-payment plan is a piecework plan which pays the worker in direct proportion to his output, piece

work prices being expressed as so many unit hours per piece instead of as so much money per piece. For each unit hour produced by the operator, he is paid his hourly base rate. In order to determine his earnings, he merely has to multiply the unit-hours credited to him, by his hourly base rate.

Hourly base rates for experienced operators have been established for all classes of direct-labor work in the factory, and each worker is assigned an hourly base rate according to the class of work he performs.

Highly Skilled Men.—Special provision is made for rewarding men of exceptional skill and versatility who are called upon to do out-of-the-ordinary jobs by assigning to these employees an hourly base rate higher than that called for by the particular class of work performed.

Although an experienced operator working at an average piecework rate of speed will produce 1.2 unit hours of work per hour, thereby earning 20 per cent over and above his hourly base rate, operators of unusual skill will produce considerably more than this and their earnings will be proportionately higher. No restriction is placed on output provided the quality is satisfactory. In each case the unit hours allowed for performing an operation are based on first-class work, and only good work is paid for unless spoilage is beyond the worker's control.

The plan guarantees each worker his hourly base rate of pay on a weekly basis, and also provides a method whereby the foreman may grant allowances in addition to the regular piecework prices for conditions beyond the control of the workers.

Off-bonus Work.—The plan is applied to direct productive operations but there are jobs, amounting to a small portion of the work, which are considered not practical to measure on a unit-hour basis. This is termed "off-bonus" work or "day work" and is ordinarily paid for at a straight hourly base rate. However, provision is made for compensating a worker of above average skill working on an "off-bonus" job so that he may earn more than his hourly base rate by assigning a special hourly rate for the particular "off-bonus" job. This is referred to as a "temporary-job rate" and is ordinarily determined by taking 90 per cent of the previous 4 weeks' average piecework earnings.

As "on-bonus" work (piecework) is completed, individual workers are credited on their timecards with the unit hours of

work produced. These timecards are sent to the timekeeper's office where the records are computed weekly. The totals form the basis for measuring the performance of each worker and of each department as a whole. So that the unit-hours credited to the worker will be a fair basis for measuring production and for wage payment, allowances expressed in unit hours are granted for doing necessary extra work caused by conditions beyond his

EMPLOYEES UNIT PRODUCTION RECORD

Department #79 Foreman John Doe 13 Weeks Ending October 1, 1938

Reg No.	Name	Previous 13 Weeks Average	WEEK ENDING													Average
			7-9	7-16	7-[illegible]	7-30	8-6	8-13								
	MILLING SECTION #3															
13236	Kilroe, C. A.	1.25	1.17	1.21	1.32	1.37	1.29	1.37								
237	Katkowski, W	1.20	1.28	1.18	1.26	1.21	1.15	1.34								
239	McCrae, J.	1.26	1.38	1.38	1.38	1.19	1.18	1.14								
241	Sheridan, H. W	1.05	1.03	.90	Transferred											
242	Cressey, A. T.	1.43	1.43	1.42	1.44	1.44	1.43	1.45								
244	Bertrand, B. W.	1.22	1.30	1.33	1.25	1.35	1.37	1.35								
245	Palin, D.	1.33	1.35	1.30	1.34	1.39	1.34	1.29								
246	Small, A. G.	1.27	1.36	1.37	Out	Out	Out	1.25								
247	Wood, G.	1.33	1.25	1.38	1.40	1.38	1.39	1.40								
248	Northup, P. C.	1.28	1.26	1.42	1.4[illegible]	1.41	1.45	1.39								
249	Corrigan, W. R.	1.38	1.39	1.40	1.39	1.36	1.34	1.42								
254	Smith, C. H.	1.26	1.31	1.36	1.30	1.29	1.27	1.28								
255	Higgin , O.	1.37	1.36	1.31	1.38	1.36	1.27	1.42								
256	Trask, J. S.	1.28	1.25	1.19	Left											
258	Harris, R E.	1.08	1.09	1.04	1.09	1.13	1.09	1.14								
260	Rayner, J. E.	1.33	1.27	1.33	1.35	1.37	1.35	1.16								
265	Hamilton, L. F.	1.39	1.35	1.40	1.41	1.39	1.44	1.47								
271	Hayman, F. G.	1.30	1.40	1.38	1.32	1.25	1.22	1.32								
276	Wood, C. K.	1.23	1.22	1.30	1.28	1.31	1.31	1.33								
	(Average)	1.27	1.28	1.29	1.35	1.33	1.30	1.32								
	Beginners															
13306	Brooks, T. E				.69	.75	[illegible]	.85								
307	Johnson, R.				.80	.83	.95	1.02								
	(Average)				4	.79	.84	.94								
	(Section Average)	1.27	1.28	1.29	1.27	1.27	1.[illegible]5	1.28								

This st[illegible]ment is for the information of the foreman or sub foreman and the individual employee only

FIG. 128.—The Employees' Unit Production Record is particularly valuable to foremen and subforemen in determining the men in the department who for some reason require help from supervisors.

control. These allowances are made out on red cards and the worker is properly credited. They are then charged against the department responsible.

An "Employees' Unit Production Record" listing the workers on bonus and showing for each worker his "unit production" for the previous week is furnished the department foremen and the subforemen each week, several days before payment of the weekly earnings. This record also shows the employees' unit production for each of the preceding weeks in the quarter and his average unit production for the previous quarter. The employees' unit production on bonus is determined by dividing

the unit-hours on bonus by the actual hours on bonus. This is a convenient figure for judging for production of the individual worker. Such a record is shown in Fig. 128.

Spots Low Productions.—The Employees' Unit Production Record is for the information of the foreman or subforeman and the individual employee only. The worker who wishes information regarding his performance asks his subforeman, who has a copy of the unit production record. This record sheet enables

WEEKLY LABOR REPORT

DEPARTMENT #79 FOREMAN John Doe 13 WEEKS ENDING October 1, 1938

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		Direct Labor					Unit Production					Actual Hours per Net Unit Hour Produced				
Week Ending	Total Direct and Indirect Labor	Actual Hours on Bonus	Unit Hours on Bonus	Unit Hours Paid for Rework and Allowances	Unit Hours Paid for Spoiled Work	% on Bonus of Total Direct	Workers on Bonus	Indirect Labor (16 Budget)	Dept	Extra Hours on Design Changes		Direct Labor *.810	Indirect Labor *.160	Inspection *.100	Wage Incentive *.025	Total Columns 12, 13, 14, 15, 16 *1.095
Weekly average previous 13 weeks	8896	7234	9036	250	2	96	1.25	1.22	1.27	15		.829	.155	.100	.027	1.111
7-9	7429	6013	7554	172	8	97	1.26	1.18	1.26	51		.820	.160	.107	.030	1.117
7-16	7100	5677	7242	200	13	96	1.28	1.14	1.26	22		.814	.164	.111	.028	1.117
7-23	7382	6115	7647	109	9	97	1.25	1.29	1.28	31		.816	.143	.108	.025	1.092
7-30	6915	5726	7638	141	14	97	1.33	1.30	1.35	41		.770	.133	.115	.025	1.043
8-6	6048	4940	6434	110	7	96	1.30	1.28	1.32	14		.789	.140	.127	.023	1.079
8-13	5240	4210	5715	132	0	94	1.36	1.30	1.37	10		.765	.132	.124	.024	1.045
Weekly average above 13 weeks																

High Dept Unit Production Is Obtained By
(1) Keeping the unit hours paid for rework allowances and spoiled work down to a minimum
(2) Maintaining a high workers unit production
(3) And by maintaining a high indirect labor unit production

Dept Factor .05

* Budget effective week ending July 9, 1938.

FIG. 129.— The weekly labor report is intended primarily to give the department foremen and management an up-to-date record of the cost trend and to disclose high costs promptly so that losses may be kept to a minimum.

the foreman at a glance to tell how one man's performance compares with another's. It is of special value in picking out quickly the men in the department whose productions are low or who need special supervision.

Weekly production for each manufacturing department is expressed in unit hours and is equal to the total unit hours produced by all direct productive workers in the department after deductions have been made for spoilage and for allowances credited to workers for conditions beyond their control. These weekly figures are the basis for the weekly labor report, Fig. 129, which

is a record of the performance of the total direct and indirect labor in the department.

The weekly labor report gives the department foreman and the management an up-to-the-minute record of the cost trend in each department, disclosing inefficiencies promptly so that losses may be kept at a minimum. The department foreman studies the weekly labor report as soon as it is received and immediately investigates the unfavorable factors. It is his responsibility to take the necessary corrective steps to improve his department efficiency.

There are a number of employees who have been with the company many years and whose production is low because of their advanced age. Wherever a department foreman has such a man in his ranks, he is permitted to charge only a portion of the worker's time to the productive job. The balance is charged to a general-expense time number which is considered a part of the company's overhead cost. In this way departmental efficiency measured in labor cost is not penalized, yet older workers are taken care of.

While provisions have been made to offset handicaps for which a department is not responsible, these provisions must all have the approval of the works superintendent or his representative. These provisions are made to overcome just handicaps, and not as a method of covering up inefficiencies and poor management in the department.

Much of the success of the wage-incentive plan depends on the efficiency of the wage-incentive department. Fair time standards must be established. The rank and file of employees must have confidence in the time-study men and in their qualifications for their jobs. The wage-incentive department insists that every time-study man shall have actual machine-shop experience before he can qualify for time-study work. It also insists that the men be sympathetic to the worker's point of view. The time-study men must be open-minded and must give serious consideration to all complaints, whether justified or not.

Complaints Adjusted Promptly.—If an operator is dissatisfied with his earnings, possibly because he thinks an error has been made in setting the time for a certain job, he can go immediately to his foreman and lodge a protest. The foreman will call in the time-study man involved and the three will talk over the matter.

Usually little time elapses before such complaints are adjusted to the satisfaction of everyone concerned.

In the installation of the wage-incentive plan and in its administration, it has been constantly kept in mind that the foreman is the keyman to success or failure. In each department, the foreman has followed the installation step by step and has worked with the time-study engineer in perfecting the details for his department. With this background, the foreman has a thorough knowledge of the operation of the entire plan, and having satisfied himself as to its value and fairness to all parties concerned, he is in a position to effectively operate the plan in his department and to pass his confidence along to his subforemen and workers.

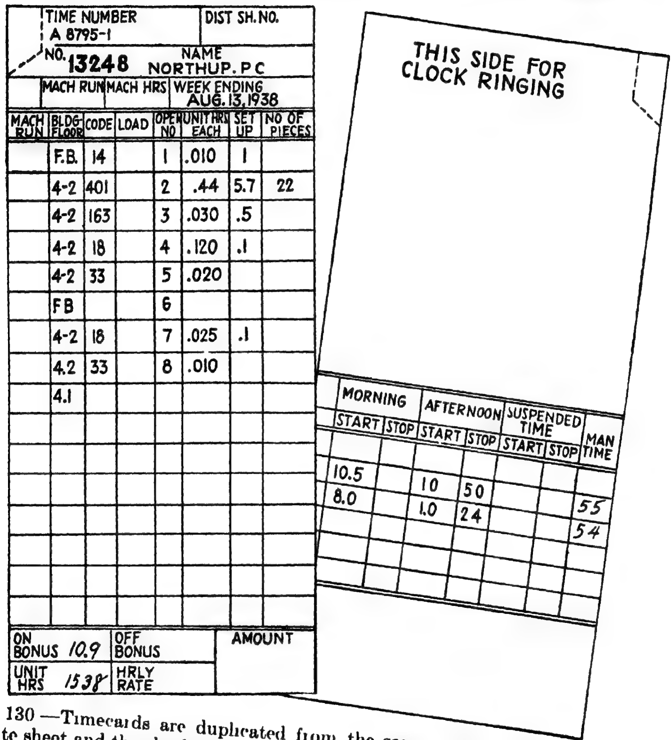
Time-study tables, based on detailed time studies, have been prepared for most of the machining operations and are used in setting unit-hour values. The foremen and the subforemen in direct charge of machine operators have helped substantially by working with the time-study men in developing these time-study tables.

In a plant such as Brown and Sharpe's, which manufactures a wide variety of products, it has been found desirable and profitable to have the detailed instruction cards prepared by a central department. Instruction cards are usually made out by the time-study section of the wage-incentive department and are filed in each department for the work done there. They are given to the operator when he is assigned a job. These cards give necessary instructions for getting a job done in minimum time including required feeds and speeds on machining operations, and any unusual specifications regarding quality. They also show the unit hours (piecework prices) for the operation, a description of the operation, the part description of the operation, the part description and part number, kind of machine, and the number of machines that are to be run by one operator.

The unit hours allowed each operation for each part are indicated on a master route card which is filed in the production-control department. When an order is released, a duplicator master is made of the master route card with the specified dates for starting each operation. From this duplicator master the route sheet (manufacturing order), which lists all operations on a job and the unit hours allowed each operation, the check sheet, and the worker's timecards are made out at the same time on a

duplicating machine. The timecards, blueprint of the job, and route sheet go with the work through the shop.

The check sheets are kept in the production-control department for centrally controlling the piece counts and piece prices and for following the progress of all orders through the shop. All timecards for completed operations are posted against the



MACH RUN	BLDG FLOOR	CODE	LOAD	OPER NO	UNIT HRS EACH	SET UP	NO OF PIECES
	F.B.	14		1	.010	1	
	4-2	401		2	.44	5.7	22
	4-2	163		3	.030	.5	
	4-2	18		4	.120	.1	
	4-2	33		5	.020		
	FB			6			
	4-2	18		7	.025	.1	
	4.2	33		8	.010		
	4.1						

MORNING START	MORNING STOP	AFTERNOON START	AFTERNOON STOP	SUSPENDED TIME START	SUSPENDED TIME STOP	MAN TIME
10.5		10	50			55
8.0		1.0	24			54

FIG 130—Timecards are duplicated from the same master used in making the route sheet and the check sheet which reduces clerical errors when posting to the check sheets.

corresponding operations on the check sheets. No timecards are accepted unless the piece counts and unit-hour prices correspond to that on the check sheets. This checking procedure is especially important since the proper functioning of the entire plan for controlling direct and indirect labor costs depends on an accurate accounting of the piece counts and piece prices credited to the individual workers.

In conclusion, emphasis should be put on the vital part played by fair and impartial administration in making this wage-incentive plan a success. It has worked out admirably because everybody connected with it, from the management down to the subforemen, has had full justice to the workers constantly in mind.

Timecards are seen in Fig. 130.

SUGGESTIONS

Suggestion Boxes.—Suggestion boxes can be a success or a failure according to the way in which they are used. They should not be introduced without careful consideration of the work they impose on management. Unless they are properly conducted, they will not only fail to produce good results, but they may easily have the opposite effect.

Installing suggestion boxes is an invitation for all employees to submit their ideas as to how improvements of any kind can be made. These suggestions may vary from unworkable plans for profit-sharing to how often the windows should be washed, or how the boss should address the watchman. Some may seem impertinent, but few are so intended. Many will be worthless, but a few will be of value. But *every one* must be considered and answered by a competent person if the system is to function. This takes time and is expensive, especially in a large plant, but unless management is prepared to handle the plan properly, it should not be started at all.

Suggestions are likely to come in floods when the plan is first installed, and to grow less and less frequent as time goes on. Probably most of the wild and impractical suggestions will appear in the first few months. After that the majority will probably be of a higher average quality and of greater value.

Handle Tactfully.—Many suggestions will relate to management, to shop conveniences and safety appliances, and to methods of doing work; many cannot be used. All must, however, be considered by competent people and frank, straightforward answers given as to why they cannot be used. Unless an intelligent reason is given, suggestions will stop. If a suggestion is not entirely clear, it is better to ask the suggester to explain it, than to reject it as being unusable. This is a place where tact in dealing with people is of utmost importance. Suggestions which

may appear foolish are frequently due to lack of knowledge as to how business is conducted, or failure to see all the consequences involved. Careful and straightforward explanations of the reasons why the suggestions are not practicable must be given in every case.

There are instances where it may be advisable to try out a suggestion that may be of doubtful value to prove to the man that you are open to new ideas. It will also prove to him, and to others, that ideas which sometimes look good may not work. Establishing confidence between the men and management is of utmost importance, and the proper handling of suggestion boxes will help in creating a sound understanding.

Payment for Suggestions.—One of the problems connected with suggestion boxes is the rewarding of those whose ideas are valuable enough to be adopted. Some ideas are naturally of much greater value than others. Decision as to the worth of each and making the men understand the fairness of each decision are real problems and should be carefully considered before the system is established.

Unless the rewards are sufficient to warrant study of shop problems few worth-while suggestions will be made. But even more important than the amount of the award is the way in which the whole matter is handled. Only the utmost fairness and frankness on the part of management will secure the best results.

Lump Sum or Royalty.—After an idea is considered to be worthy of adoption, the question, "How much is it worth?" is presented. In many cases it is impossible to know its value until it has been put into practice. But some reward should be paid promptly. Some give a minimum reward of $5 on the adoption of any suggestion. Some are so evidently of value that the first payment is from $25 to $100. If the ideas relate to improved methods or to improved product, they may save money for a number of years to come. In such cases it is evident that proper remuneration cannot be given by a single payment as no one knows how long they will continue to be of value. New machinery or new products may make the best suggestion obsolete at any time.

Some instances of this kind are handled on the royalty basis. The suggester receives a payment at regular intervals based on a

percentage of the savings due to his idea. This is probably the best kind of payment for all concerned. But it may require careful explanation on the part of the employer to satisfy the suggester that he is getting a fair proportion of the savings. This depends on the intelligence of both parties. Confidence in the fairness of all dealings is essential if best results are to be secured.

Putting a price on the value of a suggestion is very difficult at times. A very small saving on an operation that is repeated thousands of times may amount to more than a much larger saving on some operation that is done on an occasional job. Sometimes the most spectacular suggestions have little money-saving value. Time, an understanding of the shopman's point of view, a lot of diplomacy, and a reputation for fair dealing are all necessary to get the best results from any suggestion-box installation.

RATING MEN'S VALUE TO EMPLOYER

A. L. Kress, director of industrial relations of the National Metal Trades Association has developed a method of rating the value of men in different work and explains it with reference to the manual he has prepared. When a man asks for a raise in pay or when wages are being discussed, the question "How much is he worth?" must always be considered.

Management wants the considered judgment of its foremen as to the ability of their men, in terms of concrete performance factors. They want each foreman to measure his men with the same yardstick, so that they have some consistency in judgment. Most of all, they want some facts to go on. In this task of appraising individuals and their value to the company, the only way seems to be to set up some standards of performance that foremen can use to check their own judgment against.

The Metal Trades' Manual on Employee Rating says:

> Management is constantly faced with the problem of how to appraise the performance of employees fairly. How does one employee compare with another in terms of performance and value to the organization? How much more, or less, is one person worth than others doing the same work? Who are promotion prospects because of their interest, knowledge of their jobs and outside efforts to improve themselves and qualify for advancement? If a man asks for an increase, is he worth it, com-

pared with other men on the same job? These questions come up all the time, and management—the supervisory force is definitely a part of management—is continually trying to answer them fairly.

Such questions can be answered on the basis of general impressions, opinions, or hunches, or by trying to appraise individuals in terms of definite performance factors. The persons who are affected by these decisions are, of course, deeply concerned. Obviously, here is one of the most concrete places to promote sound industrial relations.

Six Bases for Rating.—There is the problem which faces management. It needs the considered judgment of the foremen as to the ability of their men in terms of concrete performance factors. Management wants each foreman to measure his men with the same yardstick, so that there is some consistency in judgment. Most of all, management wants some facts to go on. In this task of appraising individuals and their value to the company, standards of performance are set up for foremen to use in checking their own judgment. Six simple, basic things are used to rate employees on—quality of work, quantity of work, adaptability, job knowledge, dependability, attitude. In order to make it easy to rate men and to give every foreman the same yardstick for rating, four specifications have been developed for each of these factors. Take dependability, as an example. The top rating on this says: 'When you give him a job to do, have you the utmost confidence that you will get what you want when you want it?' The others are similarly specified or described. Now, all the foreman must do is appraise each man just as fairly and honestly as he can. Cases of inequalities will be found, cases where men should never have been hired or never retained after they were hired. Those cases should be handled with tact and sympathy.

Purpose of Rating.—The primary purpose of employee rating is to raise the standard of performance by enlisting the interest of the individual employee in improving his own performance, and hence his rating. The individual ratings should be used in a friendly way to point out individual shortcomings. That requires a lot of tact and judgment. Some mistakes will be made in trying to do this, but they can and should be remedied. Each individual's rating should be considered as confidential and not discussed with others. That is the only way to build up confidence in the aim of the system.

Invariably, when jobs have been rated and employees classified according to occupation or type of work performed, marked differences in rates of pay between men doing the same job will be found. Obviously management wants to know if such differences are warranted.

An employee-rating plan, properly applied, can, therefore,

1. Assist management in eliminating unwarranted inequalities in rates of pay.

2. Provide a factual basis for wage adjustments or for decisions as to transfers, promotion, or layoffs.

3. Furnish a basis for appraising the new employee to determine the progress he is making and whether he should be retained.

4. Stimulate interest in self-improvement where the ratings are used in a friendly, constructive way to point out shortcomings.

The Metal Trades Employee-rating Form is shown in Fig. 131. It carries with it the specifications the foreman is to use in appraising "Bill Smith," in the form of four sets of questions for each factor. Thus, the foreman is given a definite yardstick against which to check his own judgment. This is particularly important because an employee-rating plan, to be successful, must set up some definite standards of performance for each factor rated, so that the foreman can say, for example, "That fits Bill Smith. He's always ready to go out of his way to co-operate or try new ideas."

The point values or weights given the six factors are shown in Table 15. Thus, quality of work is given 25 per cent; quantity of work, 20 per cent; adaptability, 15 per cent; job knowledge, 20 per cent; and attitude 10 per cent. The total maximum score is 100 per cent. There can be differences of opinion as to the relative weights to be given these factors. It is immaterial what weights they are given so long as men are consistently rated, for the purpose primarily is to develop a comparative picture of men doing the same job. Where there is only one man on a job, the rating shows how nearly his own performance comes up to standard.

Caution in Applying Ratings.—In the application of an employee-rating plan in a plant, a good way *not* to introduce it is to supply each foreman with a lot of rating sheets and tell him to send them in within two weeks. The entire program should be explained and discussed at a foreman's meeting. Some one

person, preferably the industrial relations manager, if there is one, should be made responsible for the program. This person

EMPLOYEE RATING REPORT

NAME__________ NO_____ TOTAL POINTS_____ GROUP_____

DEPT__________ OCCUPATION__________ CLASS_____

RATED BY__________ DATE_____ APPROVED BY__________ DATE_____

INSTRUCTIONS—Read Carefully

Each employe's ability and fitness in his PRESENT occupation or for promotion may be appraised with a reasonable degree of accuracy and uniformity through this rating report The rating requires the appraisal of an employe in terms of his ACTUAL PERFORMANCE It is essential, therefore that snap judgment be replaced by careful analysis Please follow these instructions carefully

1 Use your own independent judgment
2. Disregard your general impression of the employe and concentrate on one factor at a time
3 Study carefully the d finitions given for each factor and the specifications for each degree
4 When rating an employe call to mind instances that are typical of his work and way of acting Do not be influenced by UNUSUAL CASES which are not typical.
5 Make your rating with the utmost care and thought be sure that it represents a fair and square opinion DO NOT ALLOW PERSONAL FEELINGS TO GOVERN YOUR RATING
6 After you have rated the employe on all six factors write under the heading General Comments on the back any additional information about the employe which you feel has not been covered by the rating report but which is essential to a fair appraisal
7 Read all four specifications for Factor No 1 After you have determined which specification most nearly fits the employe place an X in the small square over it If the specification adequately fits the employe place an X in the left square If he does not quite measure up to the specification but is definitely better than the specification for the next lower degree place an X in the right square Repeat for each factor

FACTOR	R-1 R-2	R-3 R-4	R-5 R-6	R-7 R-8
What Has He Done?				
1 QUALITY OF WORK THIS FACTOR APPRAISES THE EMPLOYE'S PERFORMANCE IN MEETING ESTABLISHED QUALITY STANDARDS	DOES HE CONSISTENTLY DO AN EXCELLENT JOB? ARE REJECTS AND ERRORS VERY RARE?	DOES HE USUALLY DO A GOOD JOB? DOES HE SELDOM MAKE ERRORS?	IS HIS WORK USUALLY PASSABLE? MUST YOU SOMETIMES TELL HIM TO DO A BETTER JOB?	IS HE CARELESS? DOES HIS WORK ONLY GET BY? DOES HE OFTEN MAKE MISTAKES?
2 QUANTITY OF WORK THIS FACTOR APPRAISES THE EMPLOYE'S OUTPUT OF SATISFACTORY WORK	IS HIS OUTPUT UNUSUALLY HIGH? IS HE EXCEPTIONALLY FAST?	DOES HE USUALLY DO MORE THAN IS EXPECTED? IS HE FAST?	DOES HE TURN OUT THE REQUIRED AMOUNT OF WORK BUT SELDOM MORE?	IS HE SLOW? IS HIS OUTPUT FREQUENTLY BELOW THE REQUIRED AMOUNT?
What Can He Do?				
3 ADAPTABILITY THIS FACTOR APPRAISES THE EMPLOYE'S ABILITY TO MEET CHANGED CONDITIONS AND THE EASE WITH WHICH HE LEARNS NEW DUTIES	DOES HE LEARN NEW DUTIES AND MEET CHANGED CONDITIONS VERY QUICKLY AND EASILY?	CAN HE TURN FROM ONE TYPE OF WORK TO ANOTHER OR GRASP NEW IDEAS IF GIVEN A LITTLE TIME AND INSTRUCTION? DOES HE ADJUST HIMSELF TO NEW CONDITIONS WITH LITTLE DIFFICULTY?	IS HE A ROUTINE WORKER? DOES HE REQUIRE DETAILED INSTRUCTION ON NEW DUTIES AND METHODS?	IS HE SLOW TO LEARN REQUIRING REPEATED INSTRUCTIONS? DOES HE HAVE GREAT DIFFICULTY IN ADJUSTING HIMSELF TO NEW WORK?
4 JOB KNOWLEDGE THIS FACTOR APPRAISES HOW WELL THE EMPLOYE KNOWS HIS JOB	IS HE AN EXPERT ON HIS JOB? DOES HE MAKE THE MOST OF HIS KNOWLEDGE AND EXPERIENCE? IS HE A SELF STARTER?	IS HE WELL INFORMED ON HIS JOB AND RELATED WORK RARELY NEEDING ASSISTANCE AND INSTRUCTION BUT ASKING FOR THEM WHEN IT WILL SAVE TIME?	DOES HE KNOW HIS JOB FAIRLY WELL? DOES HE REGULARLY REQUIRE SUPERVISION AND INSTRUCTION?	IS HIS KNOWLEDGE OF HIS JOB LIMITED? DOES HE SHOW LITTLE DESIRE OR ABILITY TO IMPROVE HIMSELF?
Can You Rely on Him?				
5 DEPENDABILITY THIS FACTOR APPRAISES YOUR CONFIDENCE IN THE EMPLOYE TO CARRY OUT ALL INSTRUCTIONS CONSCIENTIOUSLY	WHEN YOU GIVE HIM A JOB TO DO HAVE YOU THE UTMOST CONFIDENCE THAT YOU WILL GET WHAT YOU WANT WHEN YOU WANT IT?	DOES HE FOLLOW INSTRUCTIONS AND DO WHAT YOU EXPECT HIM TO DO WITH LITTLE FOLLOW UP?	DOES HE GENERALLY FOLLOW INSTRUCTIONS BUT OCCASIONALLY NEED FOLLOWING UP?	DOES HE REQUIRE FREQUENT FOLLOW UP EVEN ON ROUTINE DUTIES?
6 ATTITUDE THIS FACTOR APPRAISES THE EMPLOYE'S OPEN MINDEDNESS AND HIS WILLINGNESS TO COOPERATE IN CARRYING OUT SAFETY AND OTHER COMPANY POLICIES	IS HE AN EXCEPTIONALLY GOOD TEAM WORKER? DOES HE INVARIABLY GO OUT OF HIS WAY TO COOPERATE? IS HE ALWAYS READY TO TRY OUT NEW IDEAS?	DOES HE MEET OTHERS HALF WAY AND GO OUT OF HIS WAY TO COOPERATE? IS HE USUALLY READY TO TRY OUT NEW IDEAS?	DOES HE USUALLY COOPERATE BUT WITH SOME RELUCTANCE TO ACCEPT SUGGESTIONS AND TRY OUT NEW IDEAS?	DOES HE COOPERATE ONLY WHEN HE HAS TO? IS HE UNWILLING TO TRY OUT NEW IDEAS? DOES HE HAVE LITTLE INTEREST IN HIS JOB?

FIG. 131.—A method of rating employees. (*By permission of the National Metal Trades Association.*)

should work with each foreman helping him to think through a fair rating for each man.

If a company applies the Metal Trades plan and comes out with a plant average of 88 points, the chances are the ratings

have not been carefully made. The same would be true if the plant average were 52. In the first case, it is quite likely men were overrated, and in the second instance, underrated.

Where the rating plan has been properly applied, the following distribution will usually be found:

Group	Per Cent
1	2–5
2	7–15
3	60–75
4	8–16
5	2–5

These percentages are, of course, only approximate. Under normal conditions, about two-thirds of the working force will fall in Group 3.

Now let us see how this plan helps management to answer the question, "How does Bill Smith compare with other men on that job?" Suppose that rate ranges have been fixed for each job, based on the job rating. There are nine other men in the same job classification with Bill Smith and all ten have been rated. Bill himself comes out with 82 points, which puts him in Group 2. Let us assume the range from the minimum to the maximum is 10 cents per hour, for the particular job, which is on day work. Referring to Table 16 then, "Bill Smith" would be entitled to the minimum rate plus three-fourths of the 10-cent range, or 7½ cents.

It should be pointed out that where jobs are rated, the job with the highest total points should carry the highest rate range. If 200 men are rated, however, it does not follow that the 10 men who may fall in Group 1 should necessarily be the 10 highest paid men in the plant or that all receive the same rate. The results of the employee-rating plan must always be interpreted in connection with the specific jobs on which the men are employed. The ratings may show a Group 1 man on Class *C* welding and another Group 1 man on Class *A* welding. This simply means that each man is the best within his own job classification.

In conclusion, the following points should be kept constantly in mind in applying any employee-rating plan:

1. An employee-rating plan may be applied to advantage even though jobs have not been rated. It will be even more helpful, however, where it is used after jobs have been rated. In the first instance some kind of a job classification should be set up.

2. Foremen are the keymen in the actual rating. They must understand the plan and be sold on its value.

3. The value of employee rating depends on the soundness of the plan and upon the fairness with which ratings are made. Personal likes and dislikes have no place in rating men.

TABLE 15.—POINT VALUES FOR RATING EMPLOYEES

Factor	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8
1. Quality of work . . .	25	23	20	18	15	13	10	8
2. Quantity of work....	20	18	16	14	12	10	8	6
3. Adaptability.........	15	13	12	10	9	7	6	4
4. Job knowledge.......	20	18	16	14	12	10	8	6
5. Dependability........	10	9	8	7	6	5	4	3
6. Attitude..	10	9	8	7	6	5	4	3
Totals......	100	90	80	70	60	50	40	30

TABLE 16.—EMPLOYEE-RATING GROUP AND PAY

Group	Point range	Per cent of wage band added to base pay	Rate of pay, cents per hour
1	91–100	100	90.0
2	81–90	75	87.5
3	71–80	50	85.0
4	61–70	25	82.5
5	60 or less	0	80.0

SELLING IDEAS IN THE SHOP

Shopmen, like the rest of us, are largely creatures of habit. They get used to certain machines and ways of doing work and do not take kindly to changes, unless they thoroughly understand them. New machines and new methods succeed more quickly if the idea is sold to the men before they are introduced. Prejudice against either machines or methods and opposition to new machines make it hard for either to succeed in any shop. Many good machines have failed to show results because they were forced on the men or the foremen by an efficiency expert or a higher executive.

Many managers have found that it pays to spend time and money in educating the men and the foremen to the advantages

of new machines and methods. One way is to take the men to some shop using the machine that the management purposes to buy. This shows exactly what the machine is doing in other shops. It also makes the men feel that their opinion is considered and that they are a real part of the organization. If the men can be made to feel that they really want the new machine, its chances of success are much improved.

In some cases men become so accustomed to certain machines that they want another just like it, not realizing the number of improvements that have been made since their particular machine was built. In such cases it is even more important to have the men see how much better the new machines are. They must overcome their shyness of new devices and be shown how much more convenient the new machines are, how much easier for them to run.

Asking Advice of Men.—This is very similar to the practice of some concerns regarding new jigs and fixtures for the shop. Before the jig or fixture is actually made, the design is shown to the foreman and frequently to the man who is going to use it. Suggestions for improvement are requested, particularly as to the convenience of the clamping devices and general handiness of the tool for the operator who is to use it. Unless the men can suggest some improvements they must sign, or initial, the sketch for the part. This gives them part of the responsibility for the design and chokes off complaints regarding its convenience or efficiency after the jig is made. As one shop foreman put it, "After the operator O.K.'s the sketch, he's got to make it work to save his own face."

No management can secure the greatest efficiency in a plant without the co-operation of the men. Although in large plants it is impossible for the head man to know each individual, best results are obtained where there is an effort to keep in touch, though through fully qualified assistants. When men feel that they are really part of an organization, that their opinions are desired and respected, it is better for all concerned. When men see that there is no favoritism, when men stand on their merits, even with allowances for physical handicaps, when changes in policy are explained to them with the reasons for the change, they will be loyal to the last man.

Too little attention has been paid to selling the shopmen the fact that low labor costs reacts to their benefit in the long run, where they have faith in the management. And this faith must be built up by square dealing on both sides. J. E. Bullard points out that whereas machine efficiency has improved, there are too many cases where labor is not more efficient than before the new machines were built. He says:

All kinds of incentives fail if labor is not taught that, in the long run, greater efficiency means more pay, that labor can buy more. Costs go down as production is speeded up; selling prices drop as production is increased. More wealth is produced as automatic machines are set to work producing it, and when there is more wealth, there is not only more to divide but more that has to be divided; usually those who have had less get a greater share of the additional wealth than do those who have more.

This factor is not easy to make labor understand. Labor too often looks no farther than the next pay envelope. For this reason, profit sharing plans, bonuses paid but once or twice a year and all deferred rewards for efficient effort have a way of failing to accomplish all that is hoped from them. There is a strong tendency on the part of labor to hold back, to obstruct, even to fight progress, not realizing that all the advance which has been made by labor during the past half century has been due to progress made in the machinery field, in scientific research, in producing more at less cost. Full cooperation on the part of labor would make this progress far greater than it has been in the past. However, the tendency of labor is to gain more and more power and to use this power to slow down, rather than to speed up progress.

Where it has been given a real trial, the following plan seems to work out satisfactorily. A committee composed of those in the wage earning class who show more than the average intelligence, who can grasp the real situation and who have real influence with the other wage earners, is organized. This committee must represent the wage earners in the truest sense. Its members must be able to see both sides of a question and to see each side with as complete fairness as is humanly possible.

Having organized the best committee possible, problems are talked over with it. For example, suppose prices have gone so high that there will have to be curtailed production and the laying off of a great many employees unless costs can be reduced so prices can be lowered. It is found the only way to accomplish this result is to lower wages. However, the announcement of a wage cut is going to start a strike.

Where there is a good committee, a meeting is held. The committee is given the facts, and the true situation is revealed to it. The question

is what to do. In such a case, where there is a full and free discussion, the committee may suggest a temporary cut in wages and may indicate how this can be done without causing trouble with the wage earners. There are plenty of instances where this has actually happened.

Facing the Problem

The problem of lowering costs, however, may have a different solution. It may mean the use of more modern and more efficient machines. It may mean that each man will supervise or operate more machines and that there will be the firing of a good many of the employees. This is an even more serious situation than the first case. It is obvious that some who are now employed are not going to be continued in employment. Such a change, sprung suddenly, means trouble.

In this case the whole matter is gone into with the committee. It is explained that the step must be taken if competition is to be met. It is brought out that competition is not confined to the firms in any one industry. A more serious competition may be between one industry and other industries. If the price of cotton cloth, for example, goes too high, people wear less cotton. They turn to silk and rayon.

All this is gone into. The net result is suggestions in regard to the program to be followed in making the change. Perhaps the working week is shortened to a degree which makes it possible to retain everyone on the payroll but at a temporarily reduced wage.

The plan finally adopted is the one which the committee approves. It goes back and sells the idea to the others. As a result, production jumps to a much greater degree than would be the case if everyone did not believe that is the way to get back to the old weekly pay envelope and to make the amount in it even greater.

The employer must understand the employees and their problems. The employed must understand the employers and their problems. In very small firms this is likely to be the situation. The employees see the boss every day. He may work alongside them. They talk things over with him. They make him see their side, and he makes them see his side.

The committee idea is merely applying the same plan to larger concerns. It works exactly as well. With a committee composed of open-minded members and with employers who are open-minded, all problems which come up can be solved to the satisfaction of all concerned. The net result is that the lowest possible costs of production are reached for the simple reason that there is real cooperation. Where such plans as this are in effect, it is often the case that the wage rates are higher than the standard for the industry. The increase in efficiency is made of real financial value to the employed as well as to the employer.

KEEPING IN TOUCH WITH EMPLOYEES

As it is more difficult for large-plant management to keep in close touch with employees, Burnham Finney, editor of *American Machinist*, made a survey of methods used by several large companies. These are summarized as suggestions that may be adapted to other concerns.

Company *A*, with a large plant in New England, has recently started to send a series of monthly letters to all employees to acquaint them better with what the company is doing. The letters are termed part of a "Know Your Company" program. A special letter was devoted exclusively to the loyalty and teamwork shown by the men of the New England division during one of their unusual storms. The letter was in the form of a four-page pamphlet with pictures of the storm damage at the plant. There was a letter from the vice-president to the president giving a timetable of the hurricane events as they affected the factory and saying, "I believe that every worker, officer and stockholder should know of the extraordinary loyalty shown by the New Bedford staff during the hurricane. I am not much of a story writer, so I'll let the facts speak for themselves." On page 4 was a message of thanks to all the men from the company's president.

Company *B* has made it a practice since July, 1927, to report annually to its employees on its activities. The initial report, exceptional for its day, was a brief summary of subjects immediately relating to employees, such as data on the relief plan, pension plan, home ownership, safety and health. The report has increased in size and in the subjects covered. The last issue had in condensed form some of the tabulations sent to stockholders, including data on the volume of business and orders on hand. On subjects of special interest to employees, the report was more detailed than that to stockholders.

Company *C*, which employs about 150 men, has a general manager who knows every man in the shop and who is not only the boss, but also the counselor and friend of all employees. He holds their confidence because he gives them a square deal, even when it may be detrimental to the interests of the company. Example: One of his skilled machine operators was greatly disturbed because his mother-in-law cowed his wife, and there seemed no way of putting an end to this "bull-dozing" so long as they lived closely together. The operator "spilled" his troubles to the boss who arranged to get him a job in another city, thereby enabling him to remove his wife from under the nose of her mother. Another operator was doing poor work because his wife was running around with another man. He placed his problem before the

boss who, after reviewing the facts, helped him get a divorce. Needless to say, this shop has no serious trouble with men. The *esprit de corps* is excellent.

Company *D*, also a relatively small concern, has found that its men are eager to learn the ABC's of many subjects which they read about in the papers and hear about on the radio, but actually don't understand. The manager of the company calls the entire force together out in the shop at the noon hour now and then and personally talks informally to them on various topics. One time he may tell the men how a bank operates, putting the description into elementary terms. Another time he may explain how a manufacturing company finances itself. Still another time he may speak on the first principles of economics and of the private enterprise system. These meetings, at which the men ask innumerable questions, have helped tremendously toward a "meeting of minds" between the management and the rank and file of employees.

Company *E* uses its monthly magazine addressed to all employees to explain in a series of articles the ABC's of company policies. One of the articles explains that the door to opportunity is always open in the company. As proof the fact is cited that various officers and key executives started from lowly positions. On the board of directors are men with 190 years of combined experience in the operation of the business. They began work years ago as machine hands, clerks and draftsmen. In one issue of the magazine the management outlined its responsibilities. At the end of the statement it declared, "You, too, have a responsibility. To every other employee, to the company. Most of all, to your family and yourself."

Company *F* makes it a habit to bring its employees together in large mass meetings to explain the situation whenever a major change occurs affecting company operations. The company has around 10,000 workers in several cities and the staging of these meetings is no mean task. Recently some fundamental changes were announced in the industry's marketing and pricing policies. The company immediately scheduled meetings with all employees, explaining in simple language what the changes were and what they meant to the company and how they affected indirectly each employee.

Company *G* has set aside a large room in a building at the entrance to its plant gate where the men may gather at the noon hour and smoke, listen to the radio, play cards and play pool or billiards if they wish. This action has taken many men from their former pastime of loitering along the street or around the gate and given them something to do which they enjoy.

The New York Central Railroad is a large industry in many cities through which it operates, particularly in the smaller communities.

It is endeavoring to make its importance known by signs hung in its stations telling what it means to that particular city. We quote from the sign in the Sidney, Ohio, station, "The New York Central System is a major industry of Sidney. It has 22 employees with 58 dependents. Ten own their own homes. The annual payroll is $28,000. The road pays annual county taxes of $17,303. It pays annual county school taxes of $10,423." That is one way of informing the public and local citizens of what one industry means to a city.

Bethlehem Steel Company is devoting the current number of the *Bethlehem Review*, which goes to all employees, to presenting some of the things which the management and the workers have accomplished in "making our company of outstanding service to the general public." The history of the company's growth, with the outlook for the future, is included. The company's relationship to other industries from which it purchases supplies is outlined. Bethlehem's part in community life and the management's huge job in keeping equipped to serve Bethlehem's various markets are dealt with. The fact is brought out that the personnel is active in service clubs, welfare societies and fraternal bodies, and the company is a supporter of hospitalization, public health, education, recreation and other civic activities. For more than a decade the corporation has had a pension plan for employees and the employees relief plan paid out more than $1,000,000 in the past year. A novel example of employee and public activity at Steelton, Pa., is cited. During the short-work conditions of the depression a public park was built at Steelton by the volunteer labor of Bethlehem employees and other citizens, providing permanent recreation facilities. The *Review* comments that the value of a wide range of community work is recognized, but "the fundamental general welfare depends on good business conditions, good markets, and the uninterrupted flow of production."

Company *H* employs 250 men and manages to maintain an amiable relationship with its employees without indulging in paternalism. Whenever earnings warrant, it gives the men a bonus at Christmas. It grants vacations with pay every summer. If any man is dissatisfied with his pay rates, he goes direct to the factory superintendent who conducts immediately an informal conference in which the worker, his foreman and the superintendent participate. Matters usually are straightened out in a hurry by that process. Whenever an employee is hurt or is ill for any length of time, the president drops in to have a visit with him at his home every few days. This isn't a coldly calculated call for the purpose of winning the employee's favor, but is an expression of genuine concern on the part of "The Boss." The men know the difference. About the time of the Boss's birthday every year, the men in the

shop "throw" a party for him. It is very informal, at the end of the work-day, and the company foots the bill for the food and drinks.

Needless to say, this plant is free from labor trouble.

INTERESTING THE MEN

Many shop owners complain that the average worker lacks interest in his work—that quitting time and pay day are the two main factors in his mind. This is too true in many cases, but it is the penalty we have paid for overspecialization in industry, for developing machining methods at the expense of the individuality of the worker. We are learning, however, that interest can be stimulated and that it is much better for all concerned when this is done.

In the old days the apprentice often lived with the owner of the shop. He knew all about the work that came in, its difficulties and the way they were overcome. He heard the problems discussed, he saw just how the work was done and in many cases helped to do it. The machinist was of necessity an all-round man who usually handled a job from start to finish, and it was very natural that he should be keenly interested in it. But his interest would have been killed at once if he had only drilled one-sized holes in the same piece day after day without even knowing what the piece was to be used for.

Problem Created by Subdivision of Work.—The new methods of subdivision of work are here to stay, but they must be modernized and modified so as to consider the personality of the man who does the work. For without this management cannot secure interest, and without interest, production lags, the man becomes dull or sullen, and there is no joy in the work.

Interesting men in their work may be easy or difficult, depending on both the work and the men. Exact directions or rules are out of the question, but suggestions can and will be given which can be modified by the firm's attitude or policy, and a liberal attitude on their part will be of great help to the foreman. If the management insists on the old policy of keeping the men in ignorance of their work, the foreman who wants to climb into bigger and better work had better hunt a new connection—he cannot grow much in such a place.

The direct question is, how can a foreman help to interest his men in their work?

First of all by being sure that they understand what they are doing and *why*. If the department makes only a part of the complete product, let the men know about this part—what it does, why it must be made well, and what the output must be to keep the production of the whole plant up where it belongs. Keep the idea of quality always uppermost. Show them the advertisements and try to make every claim come true to the customer.

Be sure that each man knows just what part he plays in the complete unit. Show how slighted work will affect the whole product, how this hurts the reputation of the firm, means loss of orders and laying off of men, and harms all concerned.

The more the men know about the material they work with the better. It is another point which can be emphasized to increase interest. Where do the iron and copper and coal come from? How are they mined? How do they get here? What do they cost? How do we get brass and aluminum? What is the difference between brass and bronze?

Photographs of the product in use in various parts of the country—and of the world—together with maps with the distance marked from the factory to the different points, all help to arouse interest in the work. If there are foreign workers, any photographs of their own country, particularly in connection with the product, can hardly fail to arouse and maintain interest.

Connect the Worker with His Work.—The main thing, however, is to connect the individual worker with his work; to make him see how his work connects with the next operation, or if he spoils this piece, that he has wasted the labor of all who have worked on it previously. The cost of the material and of the labor, the delay to the completion of the product by spoiled work, and similar problems will all help in promoting the family feeling which marked the small shop of the old days.

Some of the more progressive shops are trying the experiment of training men to do two or more operations as a means of increasing their interest. If this means the finishing of the piece, so much the better, for the completed product means more to anyone than a small part of the work possibly can mean. This must be done cautiously, however, because temperaments vary widely and it may not always work. And whatever you try, do not count on perfect results every time—you are bound to be

disappointed at times. A thing that will work perfectly with one man may fail with the next owing to a difference in the temperaments of the individuals.

There is another factor which must be reckoned with also. When some kinds of men have grown accustomed to repetitive work, they often lose the desire for a change and become almost automatons and do not care to change. But we must not forget that men who grow to want their thinking done for them in the shop are also very likely to let others think for them outside of the shop in civil or community life. And we have no means of being sure that the right men will act as leaders. It is much safer to have men think for themselves both in the shop and out.

Personality of Foreman Is Important.—The most common shop operations involve interesting mechanical facts and contain valuable lessons. They also afford many opportunities of arousing interest of various kinds and degrees, depending on the mentality of the men you are dealing with. Much also depends on the personality of the foreman and the way in which he approaches the men.

When dealing with uneducated types, with men who have never had opportunities for learning, a kind of big brother attitude will usually secure confidence and interest. The main thing is to show that you are absolutely square in all your dealings for nothing is more appreciated even by the most ignorant.

The man who snags castings can be told about the wheel he uses. The millions of little pieces of almost diamond hardness that cut small pieces of metal as the wheel rubs against the iron appeal to many minds, even of the helper type. The way the abrasive is made in electric furnaces with electricity which comes from the water power of Niagara or other great waterfalls can be made interesting. The molding and baking of the wheel, the need of care in making the wheel so that it will not burst, and what happens when it does burst unless guards are provided, all affect the man who snags castings. The safeguards, the use of goggles, and the necessity of keeping the work from jamming between the wheel and the rest are all points that can be used in various ways.

The price of grinding wheels and of other things the men use is always of interest, and it is a good thing to have men know what the tools cost. It all helps to counteract the notion that every-

thing beside the cost of labor and material is clear profit; a mistaken idea that causes much discontent.

Use of Motion Pictures.—The user of drills, even on commonplace drilling operations, will be interested in knowing how drills are made and the ways in which they should be used. The motion-picture film issued by the Cleveland Twist Drill Company on drills and drilling has proved a great help in many shops. Other films can also be obtained and the motion picture will be found to be a great help in many ways in interesting men in the machines they use as well as in those they build.

The motion picture can show them how coal, iron, and copper are mined and made into the commercial metals which they use. In a similar way, the motion picture can show them the uses of their own product under difficult and trying circumstances. If, for example, the shop product is a motor truck, motion pictures showing some of the trucks pulling out of bad holes and overcoming obstacles which could not be surmounted except for good materials and good workmanship cannot fail to send a thrill through the blood of every man who helped to build them. This, of course, always assumes that the management is big enough to treat its men fairly and plays its end of the game fairly and squarely. Unless it does, all work of this kind is wasted. The foundation must be right, and in this case the foundation begins at the top.

If the worker is shown how such apparently little things as the cleaning mixture for washing machine parts, the kind of slushing compound for preventing rust, and similar problems are given close and careful study by highly skilled engineers, their own jobs take on a different aspect. The importance of little things should be impressed on each man as they frequently overlook the effect of small things on the output or the reputation of the shop. In other words the more the average worker knows about the product and the problems of making it, the better for him and for the work. It may be necessary to tell this in kindergarten language, but it should be done.

Whether a shop is large or small, much of its success depends on the interest the men take in their work. There is, however, no one formula for interesting men, for their interest depends on a number of factors. The men themselves, the kind of work, and the personality of the management all play their part. Some

men seem to be interested only in the kind of work they themselves do, while others are glad to know how the machines they make are used and where they are going.

Bulletins.—Bulletin boards with interesting facts about the work they are doing or have done stimulates interest in many places. Shop bulletins, even if only mimeographed information about the shop, its product, and its personnel, also play an important part. Many shops find that it pays to send any printed matter to the home of the worker by mail rather than distribute it in the shop. Wives and children like to know about the place where dad works, and in some cases this has prevented labor difficulties or smoothed the way for a peaceful settlement.

Interest on the part of the men depends largely on the personality of the management. Some men inspire confidence at first contact, others have to earn it by square dealing and fair treatment, and this is the only way to retain confidence, regardless of personality. Generally speaking, the more the men know about the business the better. It increases their interest and tends to prevent unreasonable demands. The more men know about the cost of doing business, in addition to the actual labor cost, the better. Otherwise they cannot be blamed for getting an exaggerated notion regarding profits. When the labor cost on an article selling for $1 is 10 cents or less, profits look exorbitant to the men unless they know of the other costs that enter into the picture. With this in mind, some concerns publish a detailed account of the year's business with all items listed, to show their men just where the money went. Such a statement works both ways. It shows the men how small a part direct labor plays in total costs and tends to prevent a too liberal distribution of profits in the way of dividends. Wise management usually construes excess profits as a signal to create a good nestegg, within reason, or to reduce prices so as to widen the market. This assumes that the product is one in which sale depends upon price and not on the number that can be used economically by industry.

A clear statement as to the costs aside from labor is valuable from many points of view. It brings out the cost of shop overhead and of sales where everybody can see them. It frequently shows that more money can be saved in selling, in handling, and in shop overhead than by reducing the direct labor cost either by cutting wages or by putting in a new machine. On the other

hand, it may easily show that some machines should have been junked long ago and even that dull drills, taps, and milling cutters are reducing production on expensive machines far in excess of the cost of the tools themselves.

Live shopmen are all interested in these problems because they directly affect their work and their earning capacity.

Periodical open house in the shop, so that men can bring their wives and children to see the work they are doing, has been found an excellent way to maintain interest, both on the part of the men and their families. Wives who only think of the shop as a place in which their men get dirty clothes are often greatly impressed when they see some of the fine machines they build. Some shops find this a very effective way of building morale both in the shop and at home.

CHAPTER 11

INSPECTION AND ASSEMBLY SYSTEMS

Inspection may be defined as an effort to ensure the production of parts or machines that will be satisfactory to both maker and user. Inspection extends from the casting, bar or plate stock, forging, or other material to prevent work being performed on defective raw material, up to actual running tests of the completed product. It also includes parts or units purchased for use in the completed product. It may vary from a casual visual examination of one of a large lot to one or more 100 per cent inspections of each part and of the finished machine. The amount of inspection and the way in which it is conducted must be determined by the management. Then comes the selection of the method, or routine, which seems best fitted for the work in hand.

AMOUNT AND KIND OF INSPECTION

Both the amount of inspection and the methods used vary widely with the kind of product, the way in which it is made, and the quantity produced. In a small shop with skilled men, each man is frequently his own inspector. This is extended in some few cases to shops of perhaps 150 men, where none but skilled men are employed. A skilled man who is proud of his job is usually reliable enough not to pass work that will be unsatisfactory to the customer. There are, naturally, but few plants where such a system, or lack of system, would be at all satisfactory.

The other extreme is where the workman is only responsible for quantity, not quality. Here the inspector starts every job and checks the first few pieces that come from the tools, which have been set and adjusted by an expert. The inspector returns at frequent intervals and checks work as it comes from the machine. In addition all parts go to an inspection room where each piece is checked for all its dimensions by suitable gages. This, as has been pointed out, is the other extreme. Between

the two methods there are many modifications that must be considered by management in order to secure the one best suited to the needs of the particular plant.

Where parts are made by semi-automatic or automatic machines, the tools can usually be depended on to make parts that are within the required tolerance over a fairly long period. The tool wear can usually be checked by periodic inspection, the time between inspections depending on the material, the tools, and the accuracy necessary. That is particularly true on the roughing operations, where appreciable amounts of stock are left for the finishing operations. In some cases, where parts from one department are machined further in other operations, the holding fixtures of the machines act as gages for the work previously done.

Some shops supply the machine operator with gages and depend on him to keep the product within the required limits. This method requires operators with both skill and interest in the work, a most desirable combination. Without this combination frequent checking by capable inspectors is necessary. Even with inspectors, some shops supply gages to the operators for use at the machine for occasional additional checking by the man on the job.

With finishing operations, such as grinding shafts or holes on machines equipped with automatic gaging devices, the operator frequently checks the work to catch any deviation from size due to wear where such conditions are not compensated in the machine itself. The main object in further inspection is to check the accuracy of the machine and the reliability of the operator.

Using these brief outlines as a basis the question of inspection and inspection systems can be discussed from various angles.

Points to Be Considered.—There are a number of points to be considered in connection with inspection. Among them are:

1. The amount and kind of inspection necessary. This includes inspection of raw material and of parts that are purchased either partly or completely machined.
2. Tolerances set by the engineering department.
3. Under which department shall inspection operate?
4. Who shall inspect work: Operator, foreman, or inspector, or all three?

5. When and how often shall inspections be made?
6. Where will work be inspected: At the machine or in an inspection department?
7. Inspection of subassemblies and of the finished product.
8. Inspection of jigs, fixtures, and tools.

Type of Inspection.—Referring to the various points in the order given, the amount and kind of inspection necessary depend largely on the product. Although any product should be satisfactory to the user, it is evident that an apple parer requires far less rigid inspection than a precision bench lathe. The same is true of the inspection of finished parts and raw material. Bar or sheet steel for ordinary use can frequently be put in the plant with little inspection, but where the requirements are severe, each batch must pass the plant metallurgist before being used. The same is true of parts or small assemblies that go into the finished product. Here much depends on the reputation of the supplier.

In cases where parts can be reassembled at low cost, it may be cheaper to omit inspection of purchased units. It may be less expensive to assume they are right until the final assembly and replace those that do not function properly. In most instances, however, it will be found cheaper to inspect all subassemblies before putting them into the finished product. This must be determined by the management with the aid of the cost department.

Setting Tolerances.—Tolerances play an important part in the amount of inspection necessary and in its cost. One of the first considerations in economical manufacture is that tolerances shall be as large as is consistent with proper operation of the finished machine. While it is possible to work to "tenths"—tolerances of 5 to 10 thousandths are much more economical. Whoever is responsible for setting tolerances should be impressed with the fact that extra-close tolerances are expensive and that they should be specified only where absolutely necessary.

Who Controls Inspection?—Generally speaking, inspectors are seldom popular with those responsible for production. Even when they come under the production department itself, which is sometimes the case, they are still looked upon as unreasonable, if necessary, evils. In many, if not in most, shops the inspector reports to the engineering or design department. This is on the

theory that the production department is likely to be less strict where there may be a question as to the acceptability of a part or a machine. It is felt that once the engineering standards have been set, this department is most interested in seeing that the quality specifications are maintained. In some few cases, the inspection department does not report to either the engineering or design departments but is responsible only to the general manager. Some production men feel that this plan gives them an opportunity at least to argue the question of tolerances being too close, whereas with engineering in charge of inspection this is not always the case.

The decision as to who is responsible for inspection must be decided by the management.

Who Shall Inspect and Where.—Topics 4, 5, and 6 are so interrelated that they may be discussed together. Inspection personnel is another point that is open to argument. A few shops with highly trained mechanics hold each man responsible for his work and have no special inspectors. This is, however, the great exception. In most large plants there is a chief inspector and his corps of assistants. The system of inspection is varied over wide ranges, depending on both the ideas of the management and the nature of the work.

In practically all systems a floor inspector checks the first piece that come off a machine. For even if the tools are inspected in the tool room, there is a possibility that they might be altered in the setup. In some shops the operator has gages to check each piece as it comes off the machine in the case of highly accurate finishing operations. In most work, however, occasional checking is sufficient where automatic, semi-automatic, or fixed tools are used. On other operations it might be advisable to use 100 per cent inspection, for it cannot be too strongly emphasized that inspection is not so much to discover and reject poor work as to confine pieces that are below standard to the fewest number possible.

One common practice is to have floor inspectors assigned a group of machines, or a department, whose work they inspect at frequent intervals. Frequent inspection is especially important on high-production machines where a broken tool point may spoil a large number of pieces in a short time. On some other classes of work inspection need be made but seldom.

In most of the older inspection systems all parts were sent to an inspection room which was equipped with more or less elaborate gages and inspection instruments. Some rejected work could be salvaged, but it was frequently found that much had to be scrapped when no check was taken on the work at regular intervals.

Having all work go through an inspection room involves considerable handling of material, takes time, and costs money. Where parts are made for stock, they go from the inspection room to the stock room to be withdrawn for assembly as needed. With the elimination of stock rooms in many mass-production plants, more inspection is being done at or near the machine, or a small inspection room is placed in the line of material flow to save handling time and labor. These inspection rooms, or stations, are usually for one or two parts, such as valve-seat inserts, connecting rods, and the like. On extremely accurate work these inspection rooms are now kept at the constant temperature of 68 deg. F which is now an international standard. This is equivalent to 20 deg. C.

Periodic Inspection.—One variation of the usual inspection routine is of interest. A few years ago, in one motor shop the cylinder blocks had no inspection after the first checkup when the machine and tools were set up As stated intervals during the day, however, a block was taken to the inspection room and checked for all essential dimensions. It was felt that with proper fixtures and tools there could be no serious variation in the product except that which was due to cutter wear or breakage. In this case, as in others, the fixtures were designed in so far as possible to check the preceding operation. While this is not always possible, it helps where it can be done.

Some machines, such as special types of grinders, both internal and external, automatically gage each piece as it is ground. This greatly reduces the amount of inspection necessary. But even here, work with very close tolerances is inspected again before assembly. A plant making precision bearings of either the ball or roller type carries inspection to a greater degree than is often necessary in many other lines. Here, as in some other industries, parts are inspected visually as well as by gages. The smoothness of the surface receives careful attention, using reflections that are magnified up to 200 or more times. With

this magnification, surfaces that look perfectly smooth to the naked eye are often far from perfect.

Grading for Selective Assembly.—Another phase of inspection is for the purpose of grading parts for selective assembly. Cylinder bores, pistons, and piston pins are all graded by small variations and sorted so that each size may be assembled with a part having a similar variation from the basic dimensions. Selective assembly has many advantages in many classes of work, especially where close tolerances are necessary for proper functioning of the completed machine.

No single plan or place of inspection will fit all plants or products. There are many variations that will be necessary to suit different conditions. Both the amount and the kind of inspection depend on the conditions involved.

These considerations of the problem of inspection have dealt largely with products made in fairly large quantities and in mass production. They do not apply to such a large extent where the output is comparatively small. There are, of course, cases where some of the small parts are made in fair-sized lots and stored until needed. These can be inspected as in large-production shops. But the main parts of the machines are made in small lots, and inspection methods usually vary widely. Machine beds are frequently planed to templets and receive no other inspection than that given by the operator or foreman. Such machines are usually inspected as to proper functioning rather than for exact duplication of parts.

Subassembly Inspection.—Parts of subassemblies have been inspected as individual pieces by whatever method is in use in the plant. The subassemblies themselves are usually inspected primarily with regard to function but also with regard to their assembly in the complete machine. In many cases interchangeability of subassemblies is more important than interchangeability of all the parts that go to make them up. Location with and connection to other parts of the complete mechanism is most important. It requires accuracy in maintaining proper dowel or bolt locations and center distances between shafts when in place.

Inspection of complete machines usually consists of making sure that they will function properly. This includes alignment of beds and moving parts in the case of lathes, planers, grinders,

and machine tools in general. Similar conditions hold for many other machines. Methods of inspection to assure correctness of alignment vary with the machine. In the case of lathes, drilling machines, millers, and the like, the spindles are checked for alignment with the ways or table, as the case may be. A test bar in the spindle of a lathe, for example, must run true at a distance of 12, 18, or 24 in. from the spindle nose within very close limits. With machines having reciprocating parts, similar alignment must be secured and checked by suitable means. These final inspections are frequently made by the foreman in a small shop, but inspectors who are specially trained for the work are necessary where the output is beyond the foreman's capacity. The kind of inspection may also depend on the machine and the requirements necessary in service. Checks to determine these points are worked out to suit each machine.

Records of inspection are considered necessary in many cases. In addition to the copy retained by the builder, a duplicate is frequently sent to the customer with the machine. These records should show in detail the amount of variation from perfection, which is, of course, never attained. Whatever the runout of a test bar in the spindle, it should be recorded for future reference.

Inspection of Jigs, Fixtures, and Tools.—Jig, fixture, and tool inspection is generally considered separately from the inspection of product. While this might be done in a central inspection room, it is usually considered a tool-room job. In most shops this holds true whether the tools are purchased outside or made in the shop itself.

In the case of new tools it is customary to check them against the drawings or samples which frequently requires many different inspections and the use of accurate instruments. The checking operation depends largely on the kind of fixture or tool. Where center distances are important, it is frequently necessary to use ingenious methods of measurement. These can be sometimes simplified by checking on the same jig borer, or similar machine, on which the holes were bored. Much depends on how the drawings are dimensioned. The drawing room can save a great deal of shop and inspection time by care in dimensioning.

An equally important part of tool and fixture inspection is the checking of those already in use, for tools, bushings, and other

surfaces do wear and this must be detected and remedied before the tools go out for another run.

Many tools can be inspected visually for sharpness of the cutting edge. Size must of course be checked by measurement with either gage or micrometer. Some shops make it a practice to grind all tools that come into the tool room after having been in service. This is done on the theory that all use involves some dulling of the cutting edge and that it is greater economy to grind the small amount necessary to restore a keen edge than to wait for a decided dullness to occur. Most shops, however, grind tools only when the man responsible for them feels that they should be sharpened. Practically all shops inspect all tools returned to the toolcrib and grind them if necessary before putting them back in the rack. This practice avoids the possibility of a dull tool being sent out, with the attendant cost of setup and the unsatisfactory results in use.

It is customary in a number of shops to return to the toolroom two or three of the last pieces made at the end of the run. This refers particularly to small work, such as comes from punches and dies or from screw-machine setups. The condition of these pieces shows the tool inspector nearly all he needs to know about the tools. He can see whether the edges are smooth and the size right and can detect any dull or broken spots in a punch or die by the appearance of the piece. The same is true of many pieces made on screw machines with box tools or other fixed setups. These samples also show the operator who takes out the tools how they acted on the last lot. They act also as samples which may help in the next setup.

Use of Sample Pieces of Work.—A modification in connection with tool setup and inspection is the use of sample pieces of work in place of drawings. This practice is less common than formerly but may still have its place in some work. Where tools have to be set up for a job, instead of using box or other tools that are already set, the samples are found quite convenient.

Although not directly connected with the inspection of tools, the way in which they are handled and kept plays a very important part in maintenance costs and may easily affect the product. If tools are not so kept that the cutting edges are protected from injury, or if shanks or other parts used for holding them are bruised, there is sure to be trouble when they get into use.

No matter how carefully the tools may be inspected or ground, they will give trouble unless they are handled carefully and stored so that the edges and important surfaces will be protected against injury.

This protection can be secured in a number of ways. It is important that the cutting edges never contact metal until they are in the machine ready to work. Wooden shelves or wood surfaces are widely used, and linoleum is also good. Corrugated paper, such as is used in wrapping articles for mailing,

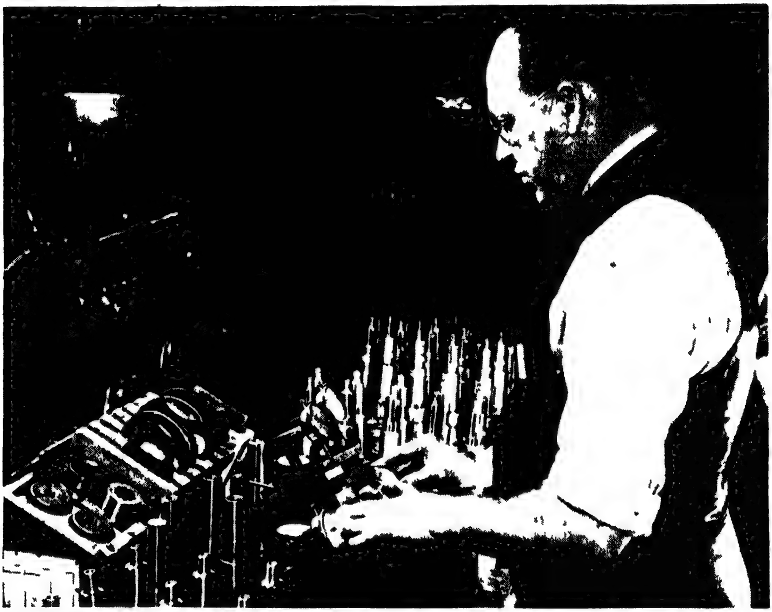


FIG. 132—Typical inspection station This is for Pontiac bevel-gear pinions.

has many good points, and while it is not a long-life material, it is easily renewed and is very inexpensive. Some tools that can be so supported that the cutting edges do not contact may not need soft material on the shelves, but all require careful handling.

Gage inspection may well come under the heading of tools but requires even greater accuracy. It also needs precision instruments that will check smaller variations than is usually necessary on tools. The inspection methods used vary widely and depend largely on the tools or gages used.

Tools for Inspection.—Methods and tools of inspection vary widely with the product. Some idea of the complexity of inspecting such a part as a drive pinion and its shaft in a modern automobile can be gained by a study of Fig. 132. This is from the Pontiac plant. This is a special functional gage that checks every diameter at once as well as the relation of one bearing fit to another. This is done before the teeth are cut so as to avoid doing work on an imperfect blank.

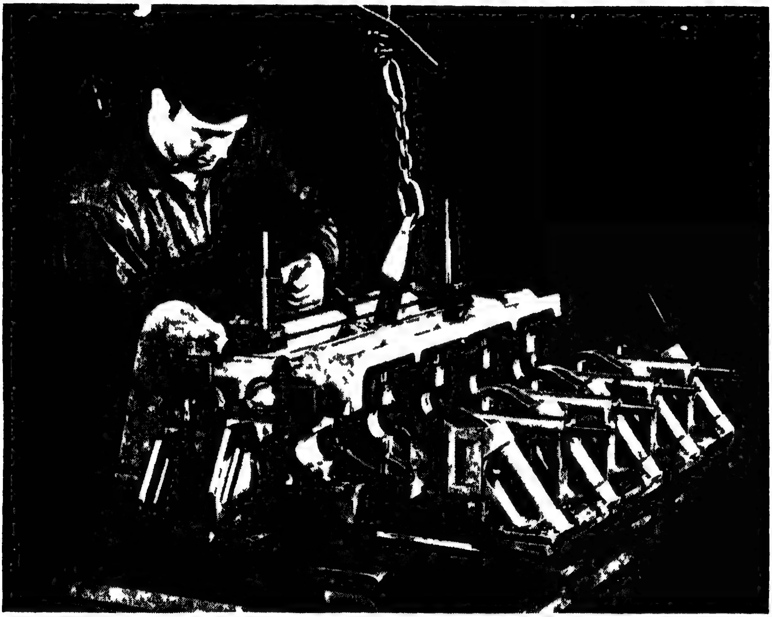


FIG. 133.—Inspecting Pontiac cylinder blocks before they go to machine shop.

The engine block test, Fig. 133, is being made in the foundry of the same plant. The gage is designed to permit a complete inspection of crankshaft and camshaft locations, cylinder bores, main bearings, and even the holes for the Welch plugs that fill the core holes in the water jacket.

INSPECTING THE ERECTION OF LARGE PRINTING PRESSES

Some of the methods used by the erectors of R. Hoe & Co. in setting up new presses in the plants in which they are to run are shown in Figs. 134–136, because it is felt that some of the

gages and methods may be found useful in other lines of work as well.

Units of large presses are aligned from a planed strip on the bed plates, which are designed for that purpose. Spacing is checked by measuring the distance between two master mandrels with a positive-length gage, as in Fig. 134. This gage has a hook or finger on one end which holds the point at the center of the master mandrel at one end, as shown in the detail at the

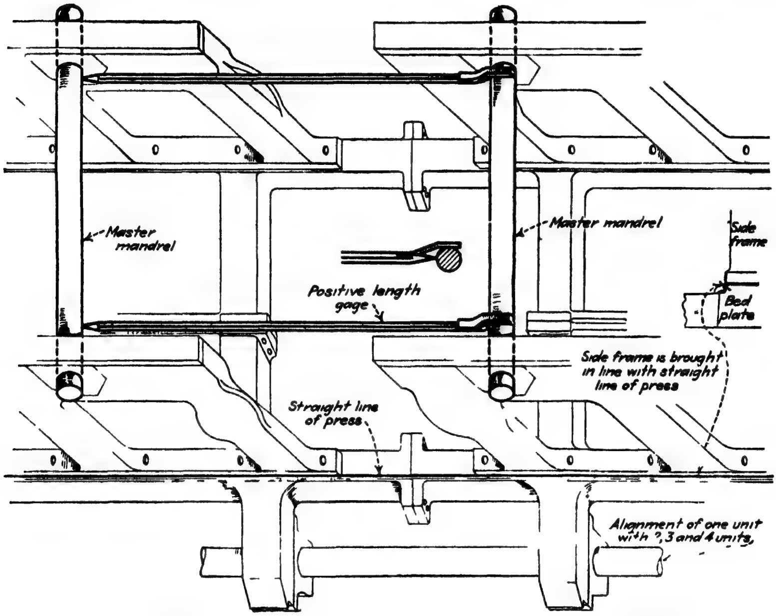


Fig. 134.—Checking alignment and center distance of shafts.

center of the cut. Several other details are also shown in Fig. 135.

The assembly in Fig. 134 includes seven shafts, of which six are horizontal. Three of the horizontal shafts and the vertical shaft are seen in Fig. 135. As all are connected by bevel gears, it is important that they are square with each other.

The forked gages shown are used to span the mating shafts and check the correct alignment. An additional gage on the shaft checks the distance of the shafts from planed pads on the press frame. This gage is shown at *A* and the method of checking is seen at *B*.

The horizontal shafts that run at right angles to the three shafts at the end are checked by the three centralizing gages, or

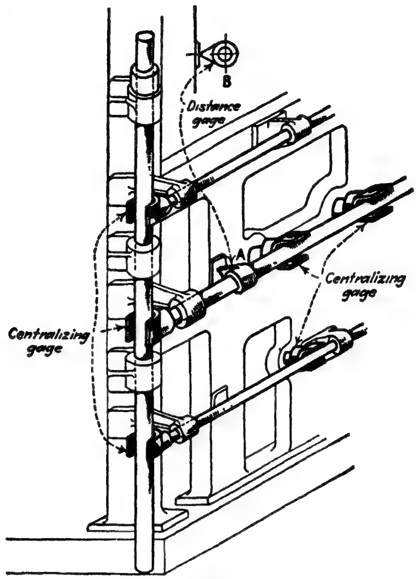


FIG. 135.—How the horizontal shafts are lined up with the vertical

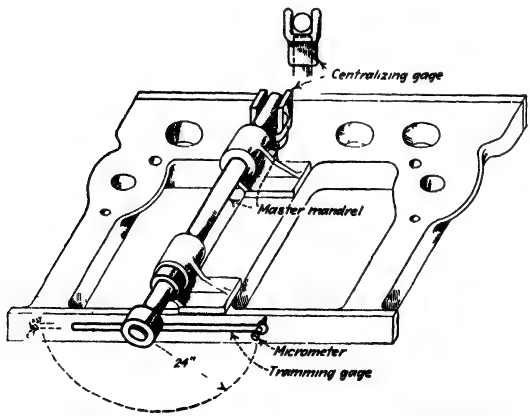


FIG. 136.—Checking squareness of shaft bearings.

forks shown on the two lower shafts. This method has been worked out to speed up the time of inspection and also ensure greater accuracy.

Squareness of the shaft bearings is checked by the use of a swinging tram as seen in Fig. 136. The tramming arm is fastened to the end of a master mandrel, and as the arm is 24 in. long, it indicates the squareness of points 48 in. apart. A centralizing fork on the vertical shaft makes it easy to line the horizontal shaft square with it.

FLYING FIELD INSPECTION[1]

Machine-shop inspectors at North American Aviation are selected both for their general mechanical knowledge and for their special familiarity with aircraft parts. The majority of the men are experienced machinists or toolmakers who have demonstrated that they possess mature judgment. The average age of the inspectors exceeds forty years.

A supervising inspector is in charge of the inspection booth. His duties include the assigning of work, approval of rejections and reworks, and assisting in the interpretation of new prints. Inspectors are usually assigned parts with which they are most familiar, resulting in a material reduction of inspection time. Junior inspectors stamp parts for inspectors and run errands.

A production control man is stationed in the booth to give priority to urgently needed parts and to split work consignments when necessary.

A tool inspector, whose duty it is to check and set plug, snap and ring gages, is available at all times.

All parts are stamped with the number of the inspector who tested them. Each inspector has three stamps: one of metal for stamping metal parts, one of rubber for stamping parts which do not permit a metal stamp, and one small stamp of rubber for the inspection record on work tickets. All parts are numbered or metal tagged with part numbers. If the material has been heat-treated, an "H.T." stamp is placed beside the inspector's; if Magnafluxed, an "M.F." stamp, etc. If the part has been inspected by the purchaser's inspector, his stamp is also affixed.

Plating on machined parts is checked by the man who makes the original inspection of the part, and plating that appears defective is rubbed with a soft rubber eraser, which cleans but does not injure the plated surface. To prevent galling and sticking of gages in plated parts, clean vaseline is applied to the gages before insertion. All external threads are wrapped with masking tape to prevent damage, and polished surfaces are protected by proper packing.

Rejects. Inspectors are instructed to state reasons for rejections simply and factually in order to avoid misunderstanding, and all nota-

[1] Lyman C. Mason, machine-shop inspector.

tions on rejection orders are required to be printed rather than in longhand. In case of rejection, parts are sent to a salvage board for disposal, and the inspector is relieved of further responsibility. Whenever possible, reworked parts are returned for inspection to the man who made the original inspection; otherwise they are 100 per cent reinspected.

The inspection staff is constantly encouraged to apply its ingenuity and experience to the end of improving inspection and production methods. Suitable forms are provided upon which inspectors are urged to suggest drawing changes that they believe will help to make a better product.

The inspection booth is directly adjacent to the machine shop. Only inspectors are permitted inside the booth; parts are placed on incoming

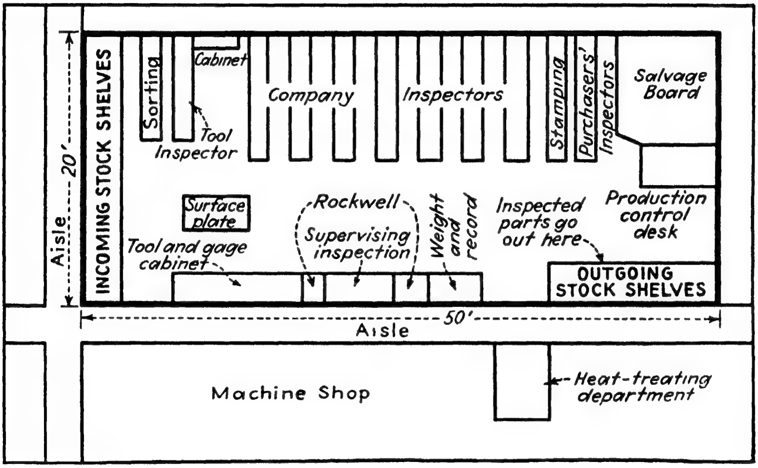


FIG. 137.—Inspection department at a flying field.

shelves, inspected and then placed on outgoing shelves on the opposite side of the booth. By this method, all stock-moving is accomplished from the outside, and there is no possibility of crowding or confusion within the booth. [The layout is seen in Fig. 137.]

The booth is airy and well lighted. Benches face north, with ample light provided by the sawtooth roof. For night work, mercury shadowless lamps are used. Neatness is required, and the booth is kept clean and orderly at all times.

Each inspector is provided with a bench, 30 × 72 in.; a comfortable stool; a surface plate 18 in. square with a wood protective cover; a self-oiling block for hardened and ground bars; a block of drills up to ½ in. in diameter. Inspectors use their own hand tools, subject to checking by the tool inspector.

Cabinets are provided to accommodate all company-owned tools, such as vernier height gages and calipers; inside and outside micrometers; dial indicators; parallels; plug gages; plug, ring and snap thread gages; special gages; templets; and angle plates. Cabinets are so arranged that each tool has its own place and does not rest against another. For larger work, a 3 × 6 ft. surface plate is also provided.

A separate cabinet is provided for measuring wires, set plugs, and master gages. The majority of the threads inspected are Class 3; a Pratt & Whitney super-micrometer may be used on them with satisfactory results. A Rockwell machine, calibrated to B and C scales, is housed on its own base in a dustproof cabinet.

SELECTING INSPECTORS[1]

Two striking facts have emerged from a recent research aimed at improvement in the inspection of certain metal products. One of these is the existence of an inherent perceptual ability which distinguishes high-grade inspectors. The other is the marked increases in production attained by training as inspectors those operators who have this high inherent ability.

In developing test devices to measure this basic inspection ability one of the first and most surprising results was the discovery of the unexpectedly wide range of this ability, both in the working inspectors and in the unselected applicants for jobs. Long service as inspectors did not materially increase ability as measured. In fact, both the tests for basic inspection ability and the careful analysis of samples of the actual work pointed definitely to the conclusion that not more than 15 per cent of the inspectors on such work were really qualified and competent to do it by reasonable standards. This is a strong statement, but the facts warrant it.

Let us examine the results of a test of inspection ability shown in Table 17. This was a work-sample performance test involving the separation of 50 defective parts from a lot totalling 100. Each applicant or employee was given a demonstration, with instructions on what was to be done and some practice on the test to demonstrate that the instructions were understood. Then the test was timed and scored for errors. What are the results?

Four applicants were able to do the test in an average time of three minutes, and 21 did it in four minutes. But the average applicant required more than six minutes to complete the test and some required more than twice that amount of time.

Did the employed operators do better? None of them did as well as the four best applicants and one was as poor as the poorest applicant.

[1] Chas. A. Drake, industrial psychologist.

On the average they were much like the unselected applicants. Apparently, selection by interview and the automatic elimination by experience had not been effective in obtaining superior ability.

This test was also scored for errors. How did the experienced operators compare with the applicants? One would expect the former to be more discriminating on parts similar to the ones they were handling

TABLE 17.—TWISTED ROD INSPECTION TEST

Time, minutes	Applicants	Operators
2 50– 3 49	4	
3 50– 4 49	21	2
4 50– 5 49	48	7
5 50– 6 49	83	11
6 50– 7 49	63	9
7 50– 8 49	28	4
8 50– 9 49	17	2
9 50–10 49	10	1
10 50–11 49	5	2
11 50–12 49	1	
12 50–13 49	2	1
13 50–14 49	1	
14 50–15 49..	1	1
Total	284	40

daily, since the least defective parts in the test were too much off-standard to permit assembly in the product. Table 18 indicates that, if anything, the experienced operators were in general not as good as

TABLE 18.—ROD INSPECTION—ERROR SCORES

Errors	Applicants	Operators	Retest, both
0	17	2	8
1	29	8	10
2	19	3	5
3	17	4	5
4	14	3	1
5	4	2	2
6	7	1	3
7	4	2	2
8	5	0	3
9	7	1	1
10 and more .	12	14	6
Totals	135	40	46

the applicants who were inexperienced. A retest of 46 of the operators and employed applicants after three months, given in the last column of the table, shows little improvement in the error scores. An examination of the improvement in the time scores of these 46 (not tabulated here) shows an average gain of less than one minute, due chiefly to the reductions among those whose first test was excessively long.

TABLE 19.—PIN BOARD TEST

Scores, time in seconds	Applicants	Operators	Operators as ranked by foreman
120–129	37	1	(31)
130–139	81	2	(2)(4)
140–149	79	6	(6)(10)(12)(13) (26)(29)
150–159	51	9	(1)(3)(5)(11)(15) (25)(30)(32)(40)
160–169	54	8	(7)(8)(9)(14)(17) (19)(23)(24)
170–179	39	4	(21)(22)(28)(33)
180–189	17	2	(18)(20)
190–199	9	4	(16)(27)(34)(35)
200–209	1	1	(36)
210–219	3		
220–229	1		
230–239			
240–249	1	2	(37)(38)
250 up		1	(39)
Totals . .	373	40	

The foregoing results indicate that the test is measuring something innate—something not materially affected by training and experience. Of course, defects of vision will influence the results of the tests. All visual perception tests, and especially the pencil-and-paper tests described later, should be given after vision has been ascertained to be normal or to be properly corrected with glasses. A good test given under standard conditions should give almost the same results each time it is repeated, with some small gain due to familiarity and practice. A large gain each time usually indicates that the test is not a reliable measuring instrument or that it is measuring something acquired by experience. Tests for innate abilities should not show marked gains of this sort.

Since the results of this test and of several other similar tests agree very well with the results of an analysis of samples of inspection work on the job, the implication is clear; select inspectors by suitable tests.

It should be noted that this particular test was made from a sample of parts actually used in production, familiar to all of the employed operators but new to the applicants. Such a test is to be preferred to the pencil-and-paper variety of test for the final selection of inspectors.

Pencil-and-paper tests, however, have certain advantages and suitable fields of application. In measuring the ability to see, or perceive, relationships the printed test permits better arrangement in order of difficulty from very easy to very hard—a most desirable feature. Moreover, the printed test is fresh and clean each time it is given and not subject to change through the wear and tear of use. Usually a printed test will require less time to give and score than a performance test requiring the handling of parts, thus making it a more convenient instrument for the preliminary elimination of applicants lacking the basic abilities required for efficient inspectors.

From a careful analysis of our results in testing for inspection ability we have been led to design several new tests of the printed variety. These tests increase in difficulty from the first line through the last line, and in order of complexity of elements through the other forms. These are designed to be given to all new applicants. Persons standing high on these tests are inferred to have the basic inspection ability for visual inspection jobs and should be given several performance tests embodying the work elements of the job itself. It is also desirable to give at least one test of general manual dexterity.

HOURLY INSPECTION[1]

The Mills Novelty Co. turns out four kinds of commercial refrigerator compressors with a high degree of accuracy in considerable quantity in one "flow" line of production. Each machine tool may be used on any one of the four by merely changing the jig. The following methods maintain accuracy of manufacture down the line and catch errors before many parts have been spoiled.

Traveling inspectors check work in process to catch errors early and make corrections in machine setups before mistakes are repeated.

A man is started off right by requiring him to have the blueprint of the part before he can draw materials, tools, jigs and fixtures for the job. The blueprint is selected from the up-to-the-minute shop file according to the number given on the "traveler" which is a form of job order card.

Having the proper tools and materials, the workman makes the first piece and no more until it has been thoroughly checked for dimensions. If the first piece is passed, he begins production. During machine operations the main dimensions are checked with gages provided for the purpose. For example, crankshafts are checked with Arnold gages

[1] M. G. Munroe.

while being ground and diameters are again checked with Zeiss micrometers after the piece is removed from the machine.

The most important phase of our inspection includes the use of the mimeographed card shown in Fig. 138. Instead of checking every piece, or checking by sampling methods, it is the job of the inspectors to go from one machine to another down the production line once every hour and thoroughly inspect one piece as it comes from each machine. If the dimensions are correct for that operation, the inspector punches the machine card O.K. If not, he notes the fact on the card.

The workman is then supposed to report the fact to the foreman who is responsible for seeing that the necessary corrections are made and that the machine is adjusted as needed. The punched cards offer a ready check as to the machine's condition to the foreman as he passes along the production line. If for any reason the worker has failed to report that his machine is not operating satisfactorily, the foreman will catch it on his regular trip following the inspector. It is this inspection that stops spoilage losses and wasted work on pieces which would otherwise get through to final inspection.

DAILY INSPECTION RECORD

Part No	Oper. No	Clock No.
Part Name		Date

A.M.			P.M		
	OK	Not OK		OK	Not OK
1			1		
2			2		
3			3		
4			4		
5			5		
6			6		
7			7		
8			8		
9			9		
10			10		
11			11		
12			12		

A card traveling with the work is checked hourly in accordance with the inspector's findings

Fig 138.— Record of hourly inspection.

The last piece to complete a run in any machine is also carefully checked. The worker is not released from responsibility and free to begin another job unless this last piece is approved.

Checked with Indicators

Every piece gets a complete check at the end of the production line before it goes into final assembly. All sorts of special gages have been devised to check critical dimensions on the compressor parts, all of them incorporating indicator dials reading to 0.0001 in. However, "go" and "not go" gages are used to measure hole dimensions because the diamond point of indicator gages cuts into the cast iron and gives faulty readings.

Since so much dependence is placed on gages throughout the shop, great care is exercised in checking them. A standing order is enforced to the effect that every gage must be checked every time it is returned to the toolroom. Johanssen blocks are used for checking.

In addition, a "precision" room has been established in which all jigs and fixtures, sample castings and occasionally parts in production are checked. A 3 × 4 ft. Taft-Peirce plate is used as a reference base for checking all dimensions. Johanssen blocks and indicator dials graduated to 0.0001 in. are used in conjunction with the plate.

INSPECTION WITH AIR GAGES

Gaging of parts, especially in connection with inspection, is a comparative rather than a measuring operation. The exact dimension in inches does not concern the inspector. His job is to see that the parts correspond with predetermined standards within the permissible tolerances.

All instruments for this purpose have multiplying devices so that "tenths" appear as coarse and easily read dimensions. Some simply flash a light for high or low limits and give no direct indication as to the exact size, as anything between the high and low limits is satisfactory.

Construction of Air Gage.—A new entrant in this field is the air gage for comparing production parts with a standard or master. These gages are built on the principle that:

1. If air under pressure is admitted into a chamber having an open orifice, a static pressure condition can be maintained within the chamber by properly controlling the entrance pressure and exit openings.

2. After such static condition is secured, any further change in the exit orifice will increase or decrease the pressure within the chamber.

3. If the static pressure inside the chamber is set low enough, a slight change in the exit orifice has a greater effect on the static pressure than the same change in the exit opening on a high static pressure.

With these principles in mind, the Spicer Manufacturing Company has made inspection gages for use in checking various parts. Some of these gages are illustrated here. They are built by applying the rules as follows:

1. The piping and drilled holes in the fixture constitute a chamber into which air is admitted under pressure. A regulating

valve in the air line ahead of the fixture constitutes the control on the entrance opening, while the plug or ring on which the piece to be gaged is placed makes the exit opening.

2. Placing the piece to be checked over the plug restricts the exit opening, and the resultant back pressure is read on the gage which forms the graduations showing the size of the hole as compared with the master, or standard, by which it is set.

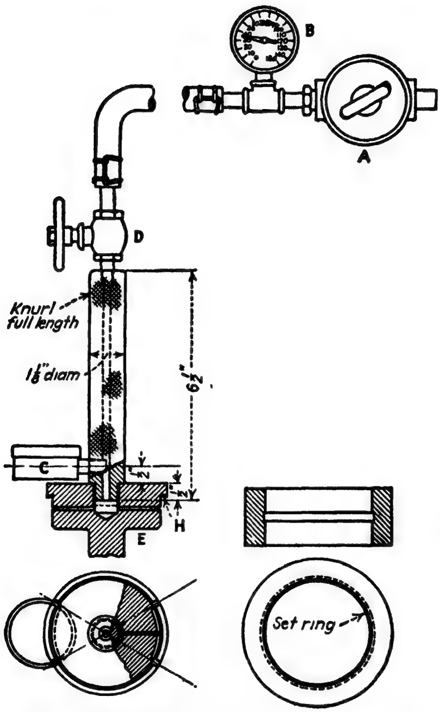


FIG. 139.—Construction of air test gages.

3. The static pressure in the gaging system is set at a pressure low enough to make a change of 5 lb. per 0.001 in. variation in the hole of the piece being inspected. This gives a wide range of movement on the ordinary 30-lb. air gage. Any desired movement of the hand on the indicating air gage can be obtained by a little experimenting.

Beginning with a gage which is connected to an air hose so as to be moved by hand from piece to piece, as in Fig. 139, we have the essentials of this method of gaging. The reducing

valve *A* regulates the initial air pressures; *B* is a gage to show initial pressure in the line; and *C* is a 30-lb. gage used for checking the exit pressure which determines the size of the piece being inspected. The $\frac{1}{4}$-in. globe valve *D* admits or shuts off air from the gaging plug *E*. This ring is screwed to the knurled handle, and is easily changed for other plugs needed on work of different sizes.

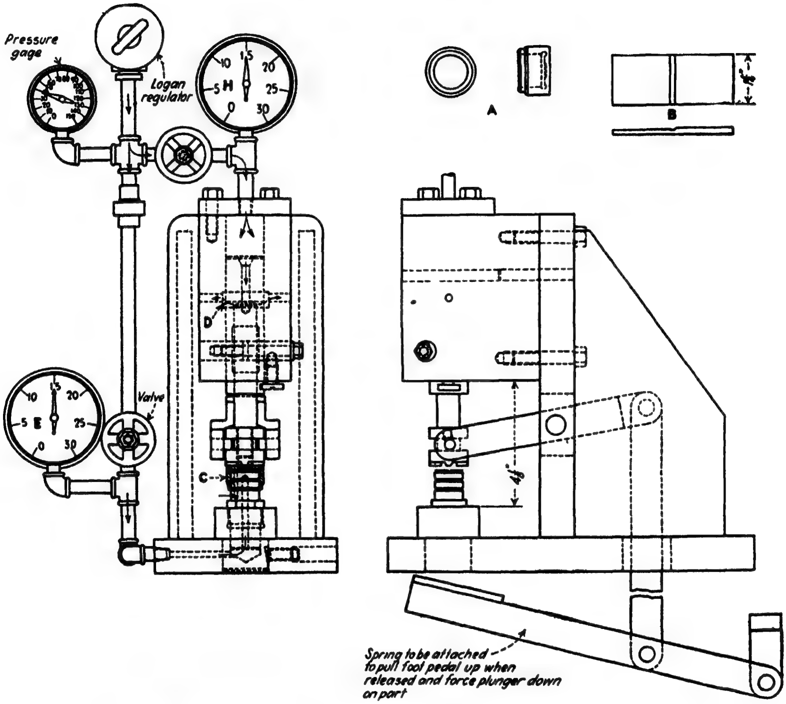


FIG. 140.—This gage measures both the bore of a cap and the thickness of its head.

The plug *E* has two small radial exit holes drilled into the central chamber. There are also small projections around the edge as at *H* to afford an opening for the air that passes out between the plug and the case being measured. The master ring is seen at the right. This has two diameters, minimum and maximum, and is used in determining where to set the pressure regulator so as to give the desired 5 lb. variation on gage *C* for each 0.001 in. of diameter variation. In this way it is

possible to permit fairly wide wear limits on the gaging plug provided the air pressure is altered to compensate for the wear. This increases gage life appreciably and forms one of the economies of this system.

In Fig. 140 is shown a gaging fixture for checking the bore of a cap and the thickness of its head. The master setting block,

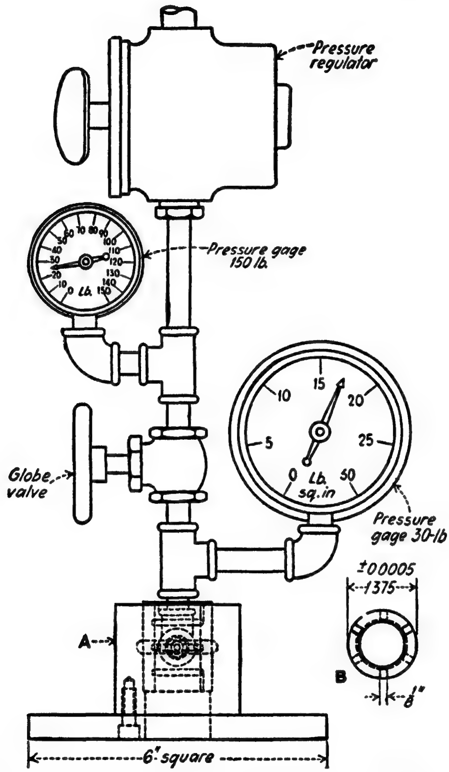


FIG. 141.—A variation of the gage shown in Fig. 139.

which is a duplicate of the cap itself, is seen at *A*. This is used in setting the air pressure for checking the internal diameter. The stepped plate or block *B* is used in setting the gage to check the thickness of the head. This gives both upper and lower limits of head thickness. The inner diameter of the caps varies from 0.769 to 0.996 in. Gage plugs for each of the ten sizes can readily be put into the machine.

Exit passages for checking the diameter are seen at C and for the check on head thickness at D. Separate gages E and H are provided for each size to be checked. The side view shows how the plunger is controlled by a pedal, which leaves both hands of the operator free to handle the work on and off the plug. This arrangement makes rapid inspection possible.

Ring Gages.—Both of the gages shown have been of the plug variety. The same method can, however, be used for shafts as in Fig. 141. The part itself which may be seen in Fig. 142 is the wing shaft for a shock absorber, and the gage inspects the shaft

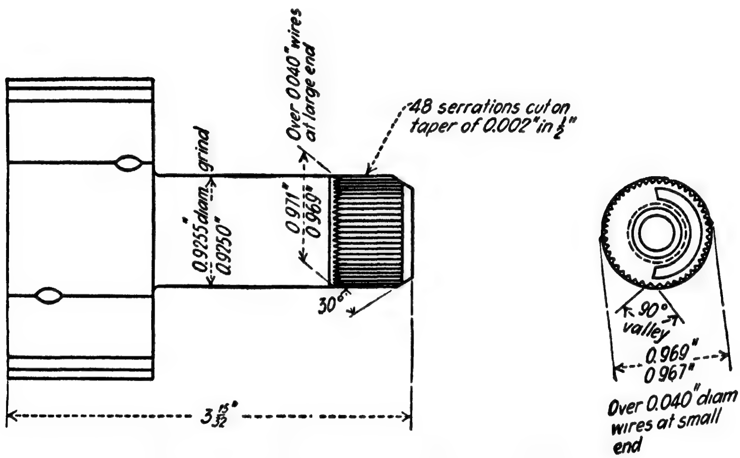


FIG. 142.—Shaft and vanes of shock absorber.

diameter below the head. In this connection, it is interesting to note the use of wires to measure the diameter at the serrated end of the shaft. The dimension is given as measured over two wires 0.040 in. in diameter.

The ring gage is held in the block A, which is screwed to the base plate over a hole that gives ample clearance. The ring gage itself is shown at B, which is given in detail so that the air-vent, or exit, dimensions can be seen. The dotted lines of the pipe connection behind the gage holder show that the gaging is done in front of the upright piping which carries the gages and the reducing valve, Fig. 191.

The accuracy with which this method will check work that can be handled in this way can be judged by noting the graduations

on the gage dial. This is a 3-in. dial and the 5-lb. marks are over an inch apart. Recalling the specifications that 5 lb. equals 0.001 in., the variations that can be checked are much finer than are needed in most manufacturing.

Several other concerns are using instruments that work on a similar principle, and they are giving excellent satisfaction. Another application in the Spicer plant is to check the squareness of holes and faces. It has been found that the best pressure to which the regulator should be set varies with the job being checked and the size of exit vents that are found desirable. Checking the pressure and the gage setting by means of the master ring or plug at frequent intervals, insures inspection that will be satisfactory.

In considering the gaging by the use of air we must not overlook the work of A. P. Steiner and his associates in connection with the Landis grinder. This method uses an air pressure of only 2 lb. per square inch, the jet impinging directly on the work being ground. When the proper diameter is reached, which is determined by the use of Carboloy-faced V blocks, the pressure built up in the line behind the jet raises the mercury in a switch that controls the grinding wheel. Strangely enough, the same method was developed in France at about the same time, another instance of simultaneous invention.

ASSEMBLY

Assembly is the final test of both machining and inspection. If the parts go together easily, both production and inspection departments are functioning properly. If fitting is required, both departments need attention. When the assembly department begins to have trouble, the inspection department should be checked immediately. If, as sometimes happens, the parts pass the inspectors' gages but do not go together as they should, the tolerances of either the parts or the gages themselves are probably at fault. The drawings probably need careful attention and probably new gages are needed.

On the other hand, there may be cases where it may be cheaper to do a little fitting than to revamp the machining department. This, however, is only safe where interchangeability is not important. It depends largely on the nature of the product. Interchangeability itself depends on how close tolerances are

necessary. Where close fits are needed in order to secure proper functioning of a mechanism, the problem becomes more serious, particularly if the mechanisms are widely scattered.

Fire-engine builders, for example, send their machines in all directions, some widely scattered. Small-town fire apparatus lasts many years, but when a part gives out it must be replaced promptly, and the part must fit the old machine even though it was made twenty or more years ago, assuming, of course, that it has not been affected by wear. Parts that wear cannot be replaced without fitting the new pieces to those that are worn. In many cases machines are so designed that the whole unit, or subassembly, can be easily replaced, for this is cheaper than fitting new parts with those that are worn. Water-pump assemblies on modern automobiles are a good example of unit replacement.

Assembly Line.—Assembly departments are laid out and managed in different ways to suit the work in hand. Machines consisting of a number of small parts, such as typewriters, are usually assembled from parts that are kept in the stock room until wanted. Automobiles, on the other hand, are assembled directly from the production, or subassembly, lines without going to the stock room at all. First the subassemblies are put together from the machine department, the parts coming by conveyor to the assembly benches or stands. Many of these units are assembled on a moving conveyor. When completed, the subassemblies are carried to the final assembly line and combined with others, into a complete automobile. Each unit, including purchased parts, is fed to the final assembly line as needed.

With parts as numerous and as bulky as those in an automobile it would be nearly impossible to provide storage and transport for several thousand cars a day, the output of some of the larger plants.

SAVING MOTIONS IN ASSEMBLY

Professor Ralph M. Barnes, who specializes in industrial engineering at the University of Iowa, gives six principles of motion economy:

1. Tools and materials should be located *around* the work place and as close to the point of use as possible.

2. Motions of the arms should be in opposite and symmetrical directions, instead of in the same direction, and should be made simultaneously.

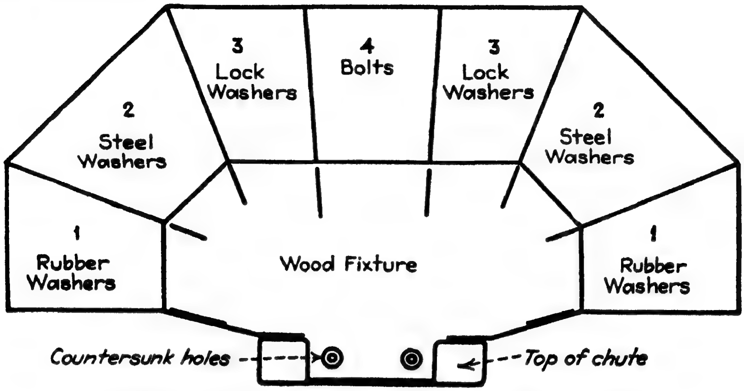


FIG. 143.—Layout of bins for bolt and washer assembly.

3. The two hands should preferably complete their movements at the same instant.

4. "Drop deliveries" should be used wherever possible.

5. Gravity feed containers and bins should be used to deliver the material as close to the point of assembly or use as possible.

6. It is usually quicker to transport small objects by sliding than by carrying

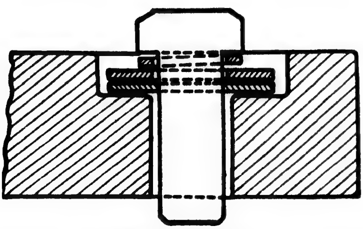


FIG. 144.—How the bolt and washers go together in the countersunk holes.

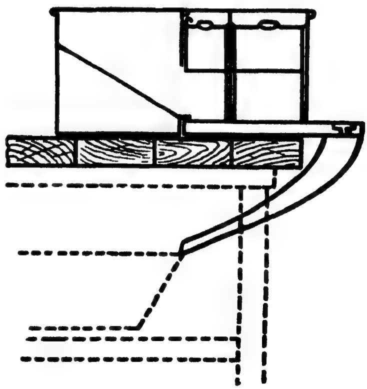


FIG. 145.—Chute to deliver bolts to pan below.

As an example he uses the assembling of three washers on a $\frac{3}{8}$-in. cap screw, the lock washer going on first, then a steel washer, and finally a special rubber washer. The original assembly bench had five bins in front of the operator, the first four con-

taining the parts and the fifth to hold the assembled parts. This was replaced by the arrangement shown in Fig. 143, the operator sitting in front and facing the bins. With both hands she reaches for rubber washer and places both in the holes in the bench, repeats this with the steel washers and lock washers and the bolts, which complete the assembly as in Fig. 144. Beside each hole is a chute so that each hand lifts the finished assemblies out of the holes and drops them in the chutes, then

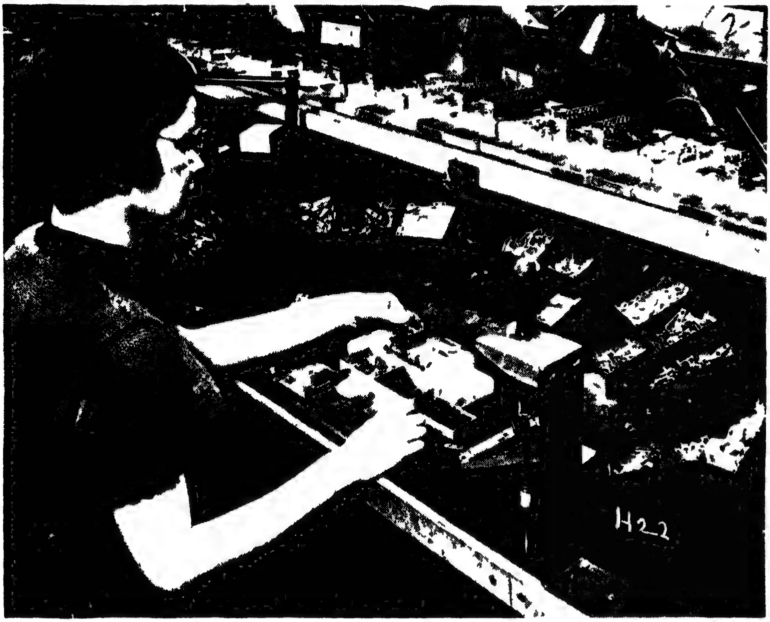


Fig. 146.—A compact assembly bench unit.

reaches for the next pair of rubber washers and repeats the operation. The new arrangement increased the output from 12 assemblies per minute to 18 per minute, an increase of 50 per cent.

A cross section of the bins and the delivery chute is seen in Fig. 145.

A somewhat similar type of compact assembly bench unit is seen in Fig. 146. This is for a more complicated assembly. A quick-action screw driver is held conveniently in a rack at the right.

Assembly from Stock Room.—Smaller products, such as business machines, are usually stocked and parts issued to the assembly department in the proper quantity for a given number of machines, even where the output is large. In the case of machine tools, such as lathes, a similar plan is generally used, even though the lot quantity is usually small. One good method is to load a set of shelves or boxes with all the parts needed for one machine. These are trucked to the assembly department and there built into a complete machine. Of course, records of the number of parts are kept so as to avoid delay or waste.

The information that follows shows how various plants handle assembly work of different kinds. Many of the methods can be adapted to other shops and should prove helpful in deciding on how to handle work of various kinds as it comes along.

Space Saved in Assembly Section

In modernizing the assembly section of its San Francisco factory, the Schlage Lock Company replaced a system of wooden-box containers with an installation of stackbins and trays to facilitate rapid and accurate handling of parts and completed product. The section occupies a space of about 200 × 100 ft. The older equipment lacked uniformity, was not neat, had the handicap of being bulky, and did not offer the necessary clear vision to the assembler reaching for a stored part. In the new arrangement, easy access to every part is provided, and as each lock is finished, it is placed in a compartment tray which is moved on rollers to the desired point. A saving of about 25 per cent in space is effected, with faster handling in assembly because of the uniform and open construction of the containers.

Assembly Analysis[1]

Manufacturers frequently find their greatest problems in assembly operations. It is the point at which all parts and subassemblies must be brought together at a given time to meet delivery schedules. Improper production planning or many last-minute changes of specifications will seriously offset performance.

Methods analysis that precede definite steps for correction of existing difficulties will often disclose many sources for improvement. One such analysis revealed that only 33 per cent of the total time was actually

[1] T. G. Lanfer, R. N. Rositzke & Associates.

needed for assembly work and that over 39 per cent of the time of experienced operators was spent on filing parts. It is obvious that the effort required at a high rate of pay in assembly can often be minimized through the adoption of proper jigs, fixtures, tools, dies and inspection control.

The basic principle involved is the reduction of errors to a minimum at the source. The ideal assembly condition is one where assemblers spend 90 per cent of their time in simply bringing together the component parts and subassemblies. A methods analysis of the effect of improper conditions upon the assembly activities will bring to light several desirable objectives.

Evaluation of the effect upon assembly costs and schedules will result in proper appropriations for improvements. Reduction of elements foreign to assembly requirements will reduce apprentice learning time and improve their progress. The shortage of skilled workers can be lessened by this means. In certain types of assembly such a program will pave the way for line assembly.

A great many manufacturers in the metal-working and machine building industries throw up their hands when they hear the words "line assembly." It is almost a religion to believe that this method of processing can be employed only by the mass-production industries. Contrary to common belief, it is not necessary to have large production of a single item or a few items in order to enjoy the partial or even complete benefits of this system. But first, it is necessary to give consideration to the following factors:

1. How many items of different specifications are normally produced?
2. Do "specials" simply have superficial or minor changes from basic specifications?
3. If present equipment is fixed and cumbersome, how flexible and light can it be made and still be effective?
4. For all items of a given type what are the differences in total assembly time?
5. Differences in the sequence of operations for various specifications should be noted. Are such differences necessary? If so, how flexible can the necessary equipment be made?
6. How clearly are operations established? Is it possible to split up excessively long operating cycles? Is it practicable to combine operations having too short a time cycle?

Conditions which may seem impossible to modify will resolve themselves upon application of an open-minded analysis. For example, in the analysis of the major item in one line of products it was found that several weeks were required for "in process" inventory and that intermediate return of items into "stores" was done to accommodate an accounting control. The product was one that required exact inspection

and observation of close tolerances and was, moreover, subject to uneven and difficult sales demands.

Several worthwhile objectives were attained by making the analysis presented in the table. This study achieved the following:

1. A decrease of 14 per cent in assembly time without increase in energy required from the operators.

2. Full inspection and correction closer to the final operation. (It was a type of assembly where correction here improved the quality. There are cases where earlier correction is essential.)

3. Skill requirements on the first operation were reduced through separating the work into three operations. Poor quality could be traced directly to the operator who is responsible.

4. Breaking-up the first operation made the item eligible for a modified form of line assembly. The bottleneck operations, when reduced to simpler activities, lent themselves to line synchronization.

5. The work in process time was reduced to less than one week.

Of course this example (Table 20) illustrates an analysis preceding the actual development of operation sequences for line assembly. The next step is to develop assembly layouts which will accommodate flexibly a number of different specifications covering a given line of product. Each item within the line must be analyzed in detail, then several steps are essential:

1. Classify all items as to over-all length of time required for completion (shortest, medium, and longest time cycles).

2. Analyze equipment necessary in finishing or assembly work as to the nature, whether fixed or inflexible, semi-flexible, light and movable.

3. Determine changes in position required of such assembly equipment.

4. Determine how assembly equipment may be made flexible through redesign.

5. Balance current delivery requirements of the various items against annual sales requirements. This will be governed to some extent by the irreducible number of people necessary on a given assembly.

6. Then determine the number of different lines desirable to: (*a*) Give necessary current delivery and schedule flexibility; (*b*) Justify investment in equipment as compared with the benefits derived; (*c*) Avoid the necessity for building excessive stocks or working force.

There are many types of assembly which will not lend themselves to line assembly even though in a highly modified form. There are others, however, where it is believed impractical, but nevertheless can be applied to good advantage. One thing is certain. There are few assembly activities that cannot be benefited by and improved through a proper methods analysis.

TABLE 20.—METHODS ANALYSIS PRECEDING OPERATION-SEQUENCE DEVELOPMENT FOR LINE ASSEMBLY

Operations before		Time allowance, minutes		Operations after	
No.	Description	Before	After	No.	Description
1	Clean parts		14 00	1	Straighten
	Assemble job		36 00	2	Assemble, drill
	Attach parts	108.00	. ...		Dowel and first adjustment
	Fit side parts	....	40 00	3	Straighten
	Attach sub-assembly	......	.. ..		Adjust and inspect
2	Broach bar	18.00	18 00	4	Broach bar
3	Put broach	10 00	29 00	5	Assemble attachment
4	Pull broach	10 00	38 00	6	Assemble springs to body
5	Assemble attachment	60.00	12 00	7	Apply spring to device
6	Assemble springs to body	33 00	12 00	8	File ends of device
7	File ends of device	17 00	15 00	9	Assemble
8	Assemble	15 00	30 00	10	Inspect and correct
9	Inspect and correct	30 00	17 00	11	Place steel mats
10	Place steel mats	17.00	17 00	12	Pull steel mats
11	Pull mats	12 00	11.00	13	Run mats
12	Run mats	12 00			
		337.00	289.00		

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